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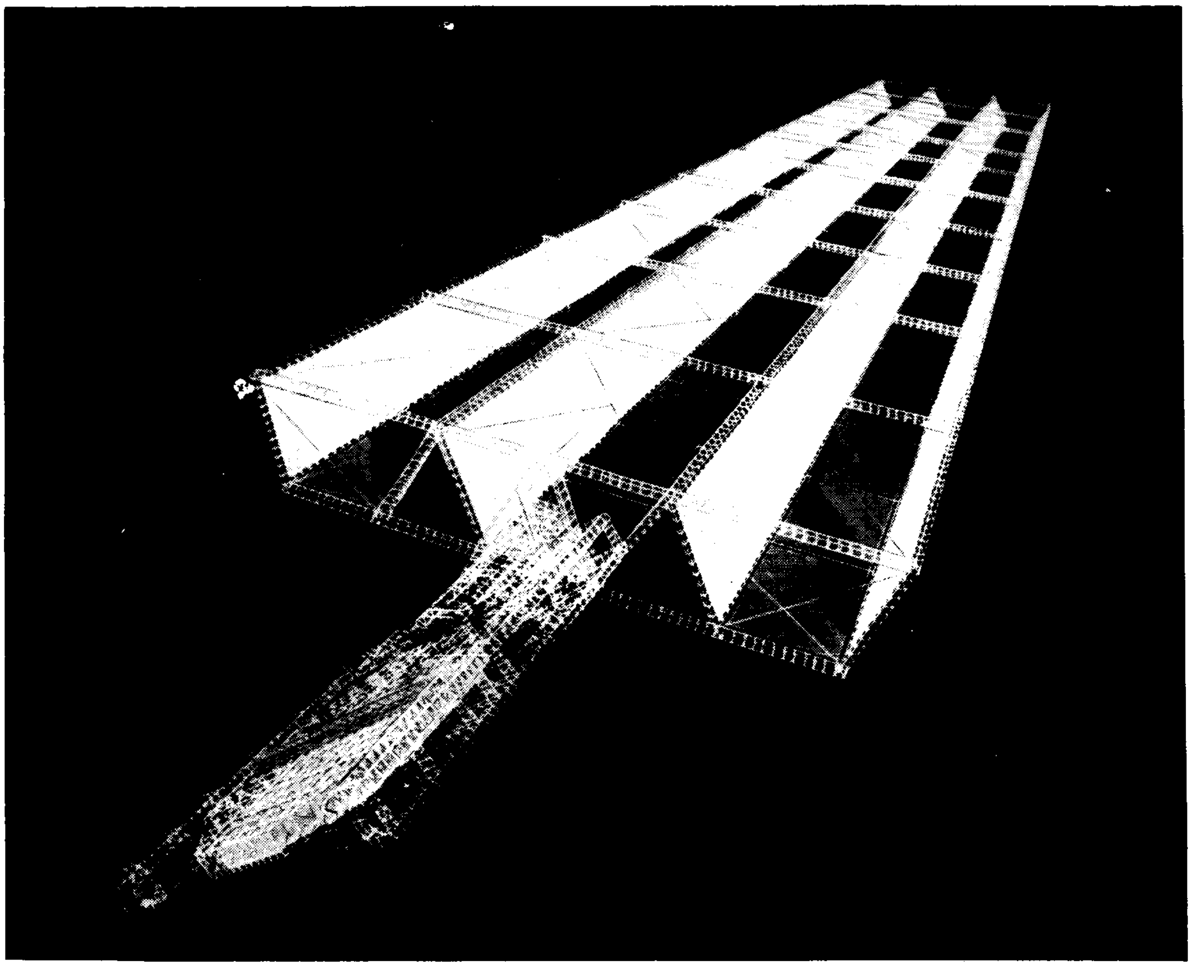

Satellite Power Systems (SPS) Concept Definition Study

FINAL REPORT (EXHIBIT D)

VOLUME VI

COST AND PROGRAMMATICS APPENDIX

Rockwell International

Space Operations and
Satellite Systems Division

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FOREWORD

Volume VI, SPS Cost and Programmatics—Appendixes, is a supporting document of Volume VI and contains the SPS WBS and dictionary, plus a presentation of cost estimates on the SPS program. This volume is submitted by Rockwell International through the Space Operations and Satellite Systems Division and reports on the work completed through October 1980. All reports are responsive to the NASA/MSFC Contract NAS8-32475, Exhibit D and Amendment 1, dated June 18, 1979.

The SPS final report provides the NASA with additional information on the selection of a viable SPS concept, and furnishes a basis for subsequent technology advancement and verification activities. Volumes of the final report are listed as follows:

Volume	
I	Executive Summary
II	Systems/Subsystems Analyses
III	Transportation Analyses
IV	Operations Analyses
V	Systems Engineering/Integration Research and Technology
VI	Cost and Programmatics
	$\boxed{\text{Cost and Programmatics—Appendixes}}$
VII	Systems/Subsystems Requirements Data Book

The SPS Program Manager, G. M. Hanley, may be contacted on any technical or management aspects of this report. He can be reached at (213) 594-3911, Seal Beach, California.

ACKNOWLEDGEMENTS

For the past five years, Rockwell International has worked on concept definitions and cost/programmatics of a Satellite Power System (SPS) involving both ground and space segments. This included a study of technology advancements, the analysis of cost/economic factors, an examination of resource requirements, and the documentation of end-to-end sequences in terms of integrated schedules and preliminary program plans covering DDT&E, acquisition, and operational phases of the SPS program. The results of this work are documented in this final report, and represent the professional contribution of many individuals, where most of them have been with the SPS program since the beginning. It is this contribution that needs acknowledgement.

Studies of SPS program development, technology advancement, and system integration were completed under the direction of F. W. Von Flue with support from a staff of competent individuals who researched and analyzed technical parameters for the development of study conclusions. The members of this SPS team include:

• Dr. L. R. Blue	Cost/Risk Computer Programming
• H. H. Chu	Computer Program Cost Data Base
• P. R. Fagan	Technology Development
• H. E. Froehlich	Schedule Analysis

The help and support of personnel from NASA/MSFC and the SPS Program Planning Office are also acknowledged.

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  - W. S. Rutledge
  - J. W. Hamaker
  - D. T. Taylor

- Program Plans and Requirements Group
  - W. A. Ferguson
  - H. K. Turner

APPENDIX A

SATELLITE POWER SYSTEM WORK BREAKDOWN STRUCTURE DICTIONARY

SOLAR PHOTOVOLTAIC CELLS
CONCENTRATION RATIO (CR)—2 EFF.
THREE-TROUGH PLANAR
END-MOUNTED ANTENNA(S)

APPENDIX A

SATELLITE POWER SYSTEM WORK BREAKDOWN STRUCTURE DICTIONARY

INTRODUCTION

Generally a work breakdown structure (WBS) is a product-oriented family tree composed of all hardware, software, services, and other tasks necessary to define the program. It offers visual display, relates project elements, and defines the work to be accomplished. The WBS is then a tool that will facilitate communications and foster and understanding of a complex program by dividing this program into less complex, more manageable subdivisions or elements. It is most desirable that this same WBS provide a uniform basis for management and control, cost estimating, budgeting and reporting, scheduling activities, organizational structuring, specification tree generation, weight allocation and control, procurement and contracting activities, and serve as a tool for program evaluation. On this basis, the WBS developed and defined herein is primarily tailored to the unique cost, economic, and programmatic requirements of the Satellite Power System (SPS). It is designed to allow a standard and logical format for estimating SPS project cost while, at the same time, permitting cost and economic comparisons of SPS to alternate and competitive candidates for producing power.

WBS MATRIX

The total WBS matrix shown in Figure A-1 is a three-dimensional structure that shows the interrelationship of (1) the hardware and activities dimension, (2) the accounts and phases dimension, and (3) the elements of cost dimension. This latter dimension is not further developed at this time, but is provided to show the overall expansion capability built into the WBS matrix. This dimension will become more important in later years when the SPS program approaches a Phase C/D start and is defined to the extent that the elements of cost can be planned and estimated with realism.

There is, of course, the fourth dimension of time which cannot be graphically shown but must be considered also. Each entry on the other three dimensions varies with time, and it is necessary to know these cost values by year for budget planning and approval, and to establish cost streams for discounting purposes.

While a multi-dimensional approach may at first appear unduly complex, it actually provides benefits that far outweigh any such concern. This structural interrelationship provides the capability to view and analyze the SPS from a number of different financial and management aspects. Costs may be summed by hardware groupings, phases, functions, etc. The WBS may be used in a number of three-dimensional, two dimensional, or single-listing format applications.

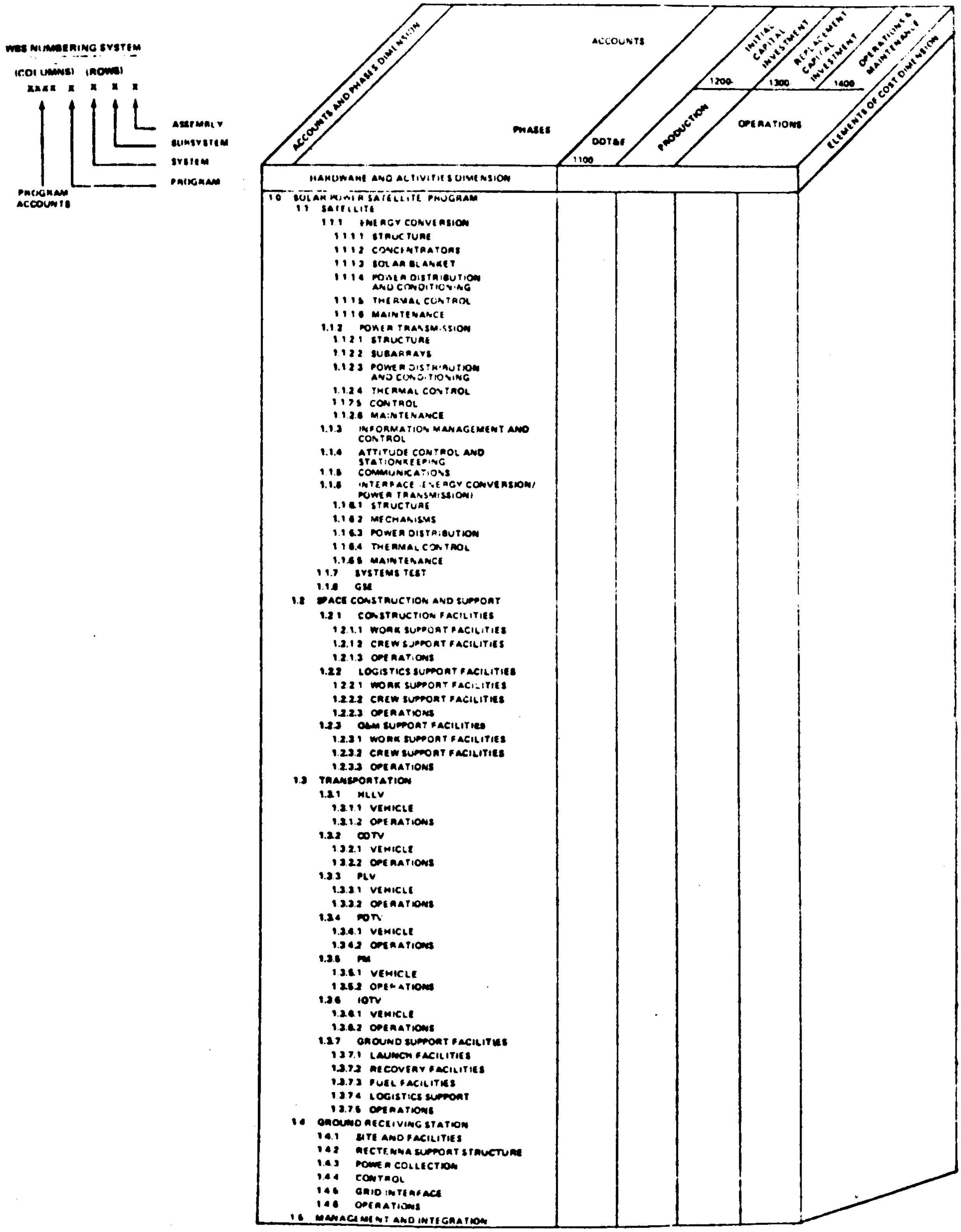


Figure A-1. Satellite Power System Work Breakdown Structure

ACCOUNTS AND PHASES DIMENSION

The accounts and phases dimension differs somewhat from the typical breakout for government aerospace programs in that it has been developed to also accommodate the financial involvement of the private sector, hence, the inclusion of the breakout of financial divisions or "accounts." Distinctions have been made between capital expenditures, which are recoverable by annual depreciation charges and are not deductible as expenses, and operation and maintenance charges against income, which are deductible as expenses in the year incurred.

To accomplish this objective, four financial accounts have been established. Design, development, test, and evaluation (DDT&E) includes the one-time costs associated with the development of components, subsystems, and systems required for the SPS project. Initial capital investment includes the costs associated with initial procurement and emplacement of the SPS plant and equipment. Replacement capital investment includes the costs associated with capital asset replacements over the operating life of the SPS (e.g., subsystem spare parts, overhauls, etc.). Operations and maintenance (O&M) includes the costs of expendables (e.g., propellants for the propulsion subsystem thrusters), minor maintenance, repair crews, etc. The interrelationship of the financial accounts to the normal aerospace program phases of DDT&E, investment, and operations are also shown in this dimension of the WBS matrix to permit traceability to these more commonly recognized terms.

HARDWARE AND ACTIVITIES WBS DIMENSION

The hardware and activities WBS dimension contains hardware elements of the satellite system and ground system subdivided into subsystems and assemblies. Inherent within this dimension is the capability for further subdivision to lower levels of detail limited only by the realism of the requirements.

Required support hardware, possibly developed under the sponsorship of other programs, is also displayed here for completeness and includes such items as space construction and support equipment and transportation vehicles. Some or all of these support elements may be developed for multiple project applications. A determination will be made later as to how much, if any, of the development costs of these support elements should be charged against the SPS program.

Each of the elements of support hardware is broken out only at a summary level within the SPS WBS. However, they each have their own detailed WBS which could be displayed in depth under the SPS WBS if required.

Finally, the hardware and activities WBS dimension also includes the necessary activities of management, integration, operations, etc., required to accomplish the overall SPS missions.

DICTIONARY ORGANIZATION

The SPS dictionary is divided into:

(1) A graphic display of the three-dimensional WBS matrix (Figure A-1)

(2) The definitions of terms of the accounts and phases dimension (pages A-5 and A-6)

(3) The definitions of terms of the WBS hardware and activities dimension (pages A-7 through A-16)

A systematic numerical coding system coordinates the rows of the hardware and activities dimension to the columns of the accounts and phases dimension such that all matrix locations are identifiable by WBS number.

Since each matrix position corresponds to one particular row of the hardware and activities dimension and also to one particular column of the accounts and phases dimension, a complete definition of any matrix position is constructed by combining the definitions from the two applicable dimensions. That is, to avoid repetition, definitions are provided only once for each hardware and activities dimension row and only once for each accounts and phases dimension column, and a complete definition for any matrix position is a combination of these two definitions.

DEFINITIONS OF ACCOUNTS AND PHASES

1100—DESIGN, DEVELOPMENT, TEST, AND EVALUATION (DDT&E)

The DDT&E account/phase consists of the one-time costs associated with designing, developing, testing, and evaluating the components, subsystems, and systems required for the SPS project. It includes the development engineering, testing, and support necessary to translate a performance specification into a design. It encompasses the preparation of detailed drawings for system hardware fabrication, system integration, and (depending on the system, subsystem, or component) structural, environmental, and other required tests. It includes all ground tests, sortie tests, subscale and full-scale SPS tests, and all hardware fabrication required for such tests. Also included are the analysis of data and whatever redesign and retest activities are necessary to meet specifications. It also includes ground support equipment, special test equipment, and other program-peculiar costs not associated with repetitive production. All SPS related support systems such as transportation, space construction base, and assembly/support equipment necessary to accomplish the DDT&E phase are included at present for completeness. It may later be determined that some of these support systems will exist with or without SPS; therefore, they may not be chargeable to the SPS project.

1200—INITIAL CAPITAL INVESTMENT

The initial capital investment account is a summation of those plant and equipment expenditures made for the initial procurement and installation of each full-scale SPS. That is, this account collects the production, assembly, installation, transportation, test, etc., costs of each individual satellite and ground station that is associated with, and necessary to, bringing the power plant online (in government aerospace terminology, this corresponds to costs in the investment phase). Examples of costs collected in this account are the procurement cost and launch cost of the satellite system itself, the procurement cost of the ground system (including installation), and all other necessary costs to achieve this end such as those attributable to space stations, launch vehicle fleets, etc. Also included is pro rata share of such functional costs as program management, SE&I, etc., related to the foregoing systems. Only costs incurred after the end of the DDT&E phase and prior to the initial operational capability (IOC) of each SPS are collected in this account.

1300—REPLACEMENT CAPITAL INVESTMENT

The replacement capital investment account is a summation of those plant and equipment expenditures made for capital asset replacement and major overhauls that are expected to last more than one year and result in an improvement to the operating system. Examples of costs collected in this account are the costs of spares, their installation and associated launch costs or ground transportation costs, permanent improvements in the system such as rotary joint replacement, installation of improved design satellite control equipment, etc.,

as well as pro rata shares of functional costs. Replacement capital investment expenditures are grouped into two categories in order to identify those costs and activities that occur before or after initial operational capability (IOC) of the SPS.

1400—OPERATIONS AND MAINTENANCE (O&M)

The O&M account is a summation of those expenditures incurred in the day-to-day operations beginning with the IOC and continuing over the life of each SPS. Examples of costs collected in this account are wages of operations and maintenance personnel, minor repairs and adjustments to systems to maintain an ordinarily efficient operating condition, expendables and consumables, launch costs for transfer of on-orbit personnel and resupply of expendables and consumables, etc.

DEFINITIONS OF HARDWARE AND ACTIVITIES

1.0 SATELLITE POWER SYSTEM PROGRAM

The program includes all the elements of hardware, software, and activities required for the design, development, production, assembly, transportation, operations, and maintenance of the SPS program systems. Included are the satellite and ground receiving station systems, as well as the necessary support systems such as space construction and support and transportation.

1.1 SATELLITE

This element includes the hardware and software located in geosynchronous orbit (GEO) for the collection of solar energy, conversion to electrical energy, and transmission of electrical energy in microwave form to earth.

1.1.1 ENERGY CONVERSION

This element includes the components required to collect solar energy, convert the solar energy to electrical energy, condition the electrical energy, and transport it to the interface wubsystem (WBS No. 1.1.6).

1.1.1.1 STRUCTURE

This element includes all necessary members to support the concentrators, solar blankets, and other energy conversion subsystem hardware. It includes structural beams, beam couplers, cables, tensioning devices, and secondary structures which are required as an interface between the primary structure and the mounting attach points of components, assemblies, and subsystems including mechanisms such as drive motors located at the interface for yoke rotation.

1.1.1.2 CONCENTRATORS

This element concentrates the solar energy onto the solar blanket to increase the energy density on the conversion device. It includes the reflective material and any integral attach points required for mounting. Excluded are tools and support equipment required for deployment and tensioning.

1.1.1.3 SOLAR BLANKET

This element converts solar energy to electrical energy and provides power to the power distribution and conditioning buses. It includes the photovoltaic conversion cells, coverplates, substrate, electrical interconnects, and any integral attach points required for mounting. Excluded are tools and support equipment required for deployment and tensioning.

1.1.1.4 POWER DISTRIBUTION AND CONDITIONING

This element includes the power conductors, switch gear, and conditioning equipment and slip rings required to transfer power from the solar blanket to the interface subsystem power distribution elements. Also included are electrical cables and harnesses required to distribute power to equipment located on

the energy conversion structure, plus batteries or storage medium for information system and attitude control. Excluded are data buses which are included in the information management and control subsystem (WBS No. 1.1.3).

1.1.1.5 THERMAL CONTROL

This element includes any component used to modify the temperature of the energy conversion subsystem components. It includes coldplates, heat transfer, and radiator devices, as well as insulation, thermal control coatings, and finishes. Excluded are paints or finishes applied to components during their manufacturing sequence.

1.1.1.6 MAINTENANCE

This element provides for in-place repair or replacement of components and includes work stations, tracks, access ways, and in situ repair equipment.

1.1.2 POWER TRANSMISSION

This element receives dc electrical power from the interface subsystem, conditions the power, converts it to microwave energy, and radiates the energy to the ground receiving station. Included are power distributions from the interface subsystem, dc-to-RF conversion devices, control and monitoring equipment, and antenna radiating elements.

1.1.2.1 STRUCTURE

This element includes all members necessary to support the transmitter subarrays and other power transmission subsystem hardware. It includes structural beams, beam couplers, cables, tensioning devices, and secondary structures, plus the mechanisms/drive gears for antenna orientation.

1.1.2.2 TRANSMITTER SUBARRAYS

This element includes all the hardware required for generation, distribution, phase control, and radiation of microwave energy. This includes the subarray structure, waveguides, power amplifiers, phase shifters and control electronics, and power harnesses. Also included are thermal control devices and finishes that are manufactured as an integral part of the subarray.

1.1.2.3 POWER DISTRIBUTION AND CONDITIONING

This element includes the power conductors, switch gear, and conditioning equipment required to transfer power from the interface subsystem to the subarray wiring harnesses and to any other power-consuming/storage equipment located on the power transmission structure, such as batteries.

1.1.2.4 THERMAL CONTROL

This element includes any component used to modify the temperature of power transmission subsystem components. It includes coldplates, heat transfer and radiator devices, as well as insulation, thermal control coatings, and finishes. Excluded are paints and finishes applied to components during their

manufacturing sequence and thermal control devices that are an integral part of another component.

1.1.2.5 CONTROL—PHASE REFERENCE

This element provides the reference phase for all subarray phase conjugating circuits. This includes the reference oscillator signal distribution equipment and components that commonly serve all subarrays.

1.1.2.6 MAINTENANCE

This element provides for in-place repair or replacement of components and includes work stations, tracks, access ways, and in situ repair equipment.

1.1.3 INFORMATION MANAGEMENT AND CONTROL

This element includes those components that process information on board the satellite. This includes sensing, signal conditioning, formatting, computations, formulaton and signal routing, plus instrumentation requirements for MWPTS voltage/control measurement on the antenna.

1.1.4 ATTITUDE CONTROL AND STATIONKEEPING

This element includes the components required to orient and maintain the satellite's position and attitude in GEO. Included are sensors, reaction wheels, chemical and electric propulsion hardware, and propellants.

1.1.5 COMMUNICATIONS

This element includes the hardware to transmit and receive intelligence among the various SPS elements. This includes communication of both data and voice between the SPS and the control center, as well as among the various cargo and personnel vehicles. Excluded is intravehicular and intrasatellite communications.

1.1.6 INTERFACE (ENERGY CONVERSION/POWER TRANSMISSION)

This element provides the movable interface between the energy conversion subsystem and the power transmission subsystem. A 360° rotary joint and an antenna elevation mechanism are required to maintain proper alignment of the transmitter with the ground receiving station. Included are structure, mechanisms, power distribution, thermal control, and maintenance hardware.

1.1.6.1 STRUCTURE

This element includes all members necessary to provide a mechanical interface between the primary structures of the energy conversion subsystem and the power transmission subsystem. It includes beams, beam couplers, cables, tensioning devices, and secondary structures. Excluded are elements of the drive assembly which are included in mechanisms (WBS No. 1.1.6.2).

1.1.6.2 MECHANISMS

This element of the interface segment includes components required to support rotation and elevation of the power transmission subsystem. Included are bearings, gears, drive motors, and passive supports. Drive motors are located on the energy conversion segment.

1.1.6.3 POWER DISTRIBUTION

This element provides for the transfer of electrical power through the interface. It includes slip ring, brush assemblies, feeders, and insulation.

1.1.6.4 THERMAL CONTROL

This element includes any component used to modify the temperature of interface subsystem components. It includes coldplates, heat transfer and radiator devices, as well as insulation, thermal control coatings, and finishes. Excluded are paints or finishes applied to components during their manufacturing sequence.

1.1.6.5 MAINTENANCE

This element provides for in-place repair or replacement of components and includes work stations, tracks, access ways, and in situ repair equipment.

1.1.7 SYSTEMS TEST

This element includes the hardware, software, and activities required for ground-based systems tests including qualification tests and other development tests involving two or more subsystems or assemblies. It includes the production, assembly, integration, and checkout of satellite system hardware into a full or partial system test article. It also includes the design, development, and manufacture of special test equipment, test fixtures, and test facilities that are not included in other elements such as ground support faciliteis. Also included are the planning, documentation, and actual test operations.

1.1.8 GROUND SUPPORT EQUIPMENT (GSE)

This element includes all ground-based hardware required in support of handling, servicing, test, and checkout of the satellite subsystems. It also includes special hardware required for simulations and training.

1.1.9 PILOT PLANT/TEST ARTICLE

The SPS proof-of-concept pilot plant and supporting test validations are included in this element. It covers a space test vehicle, STS transportation, construction operations/test activity, and ground receiving facility.

1.2 SPACE CONSTRUCTION AND SUPPORT

This element includes all hardware and activities required to assemble, check out, operate, and maintain the satellite system. Included are space stations, construction facilities, support facilities and equipment, and manpower operations.

1.2.1 CONSTRUCTION FACILITIES

This element includes the facilities, equipment, and operations required to assemble and check out the satellite system. Included are crew life support facilities, the central control facility, fabrication and assembly facilities, cargo depots, and operations.

1.2.1.1 WORK SUPPORT FACILITIES

This element includes the facilities and equipment required for satellite assembly and checkout. Included are beam fabricators, manipulators, assembly jigs, installation and deployment equipment, and cargo storage depots. Excluded are the facilities related to crew support.

1.2.1.2 CREW SUPPORT FACILITIES

This element includes the facilities and equipment required for the life support and well-being of the crew members. Included are living quarters, center control facilities, recreation facilities, and health facilities of the satellite construction base.

1.2.1.3 OPERATIONS

This element includes the planning, development, and conduct of operations at the construction facility. It includes both the direct and support personnel and the expendable maintenance supplies required for satellite assembly and checkout.

1.2.2 LOGISTICS SUPPORT FACILITIES

This element includes the hardware, software, and operations required in low earth orbit (LEO) to support the construction and operations and maintenance of the satellite system. Included are crew life support facilities, cargo and propellant depots, and vehicle servicing facilities necessary for the receiving, storage, and transfer of cargo and personnel destined for a construction base or operational satellite located in GEO.

1.2.2.1 WORK SUPPORT FACILITIES

This element includes the facilities and equipment required to provide logistics support in LEO. Included are heavy-lift launch vehicle (HLLV) and orbital transfer vehicle (OTV) docking stations, payload handling equipment, and cargo and propellant storage depots. Excluded are facilities related to crew support.

1.2.2.2 CREW SUPPORT FACILITIES

This element includes the facilities and equipment required for the life support and well-being of the crew members. Included are living quarters, recreation facilities, and health facilities of the LEO Base.

1.2.2.3 OPERATIONS

This element includes the planning, development, and conduct of operations at the logistics support facility. It includes both the direct and support personnel and the expendable maintenance supplies required for logistics support.

1.2.3 O&M SUPPORT FACILITIES

This element includes the facilities, equipment, and operations required in GEO to support the operations and maintenance of the satellite system. Included are the on-orbit monitor and control facility and the life support facilities and equipment required to provide comfortable, safe living quarters for the resident crew members.

1.2.3.1 WORK SUPPORT FACILITIES

This element includes the facilities and equipment required for operation and maintenance of the satellite system. Included are satellite monitor and control stations and any centralized repair facilities not included under maintenance (WBS Numbers 1.1.1.6, 1.1.2.6, and 1.1.6.5).

1.2.3.2 CREW SUPPORT FACILITIES

This element includes the facilities and equipment required for the life support and well-being of the crew members. Included are living quarters, recreation facilities, and health facilities.

1.2.3.3 OPERATIONS

This element includes the planning, development, and conduct of operations at the O&M support facility. It includes both the direct and support personnel and the expendable maintenance supplies required in GEO for satellite operations and maintenance.

1.3 TRANSPORTATION

This element includes all space transportation required to support the satellite system assembly and operation; and the ground support facilities to provide a launch, recovery, propellant, logistics, and operational capability. Included are the launch to LEO and the orbit-to-orbit transfer of all hardware, materials, and personnel required during the construction and lifetime operation of the satellite system.

1.3.1 HEAVY-LIFT LAUNCH VEHICLE (HLLV)

This element includes the HLLV vehicles and operations required to support the satellite system assembly and operation. Included is the launch to LEO of all personnel, space construction and support equipment, satellite system hardware, OTV's, propellants, and other consumables required throughout the satellite construction and operational lifetime.

1.3.1.1 HLLV VEHICLE

This element includes the vehicle fleet procurement required to support the SPS project.

1.3.1.2 HLLV OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the SPS project.

1.3.2 CARGO ORBITAL TRANSFER VEHICLE (COTV)

This element includes the COTV vehicle and operations required to support the satellite system assembly and operation. Included is the LEO-to-GEO transfer of space construction and support equipment, satellite system hardware, spares, and propellants required throughout the satellite lifetime.

1.3.2.1 COTV VEHICLES

This element includes the vehicle fleet procurement required to support the SPS project.

1.3.2.2 COTV OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the SPS project.

1.3.3 PERSONNEL LAUNCH VEHICLE (PLV)

This element includes the PLV and cargo vehicles of the STS (Space Shuttle), growth Shuttle, and Shuttle derivatives, including operations required to support the precursor (pilot plant), LEO base, and SCB. Also included is the launch to LEO and return of all personnel and cargo.

1.3.3.1 PLV VEHICLES

This element includes the vehicle fleet procurement to support early STS vehicle requirements for personnel/cargo transfer from earth to LEO as needed to support elements of the pilot plant, LEO base, and construction facility.

1.3.3.2 PLV OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support early SPS project activities.

1.3.4 PERSONNEL ORBITAL TRANSFER VEHICLE (POTV)

This element includes the POTV vehicles and operations required to support the satellite system assembly and operation. Included is the LEO to GEO and return transfer of all personnel and priority cargo required throughout the satellite construction and operational periods.

1.3.4.1 POTV VEHICLES

This element includes the vehicle fleet procurement required to support the SPS project.

1.3.4.2 POTV OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the SPS project.

1.3.5 PERSONNEL MODULE (PM)

This element includes the PM units and operations required to support the satellite system assembly and operation. Included is the LEO to GEO and return transfer of all personnel and critical hardware items required throughout the satellite construction and operational periods. The PM provides a crew habitat during the orbit-to-orbit transfers of personnel.

1.3.5.1 PM VEHICLES

This element includes the PM unit procurement required to support the SPS project.

1.3.5.2 PM OPERATIONS

This element includes the necessary operations (user charge per flight including payload integration) required to support the SPS project.

1.3.6 INTRA-ORBITAL TRANSFER VEHICLE (IOTV)

This element includes the IOTV vehicles and operations required to support satellite system assembly and operation. Included is the intra-orbit transfer of cargo between the HLLV, COTV, construction facility, logistics support facility, and operational satellites.

1.3.6.1 IOTV VEHICLES

This element includes the necessary vehicle fleet procurement required to support the SPS project.

1.3.6.2 IOTV OPERATIONS

This element includes the necessary vehicle operations (recurring refurbishment and propellant costs) required to support the SPS project.

1.3.7 GROUND SUPPORT FACILITIES

This element includes all land, buildings, roads, shops, etc., required to support the cargo handling, launching, recovering, refurbishment, and operations of the space transportation system.

1.3.7.1 LAUNCH FACILITIES

This element includes the design and construction of the actual launch facility and its associated equipment. Included are land, buildings, and equipment required to support the various crews. It also includes the required control centers and administrative facilities.

1.3.7.2 RECOVERY FACILITIES

This element covers the design, construction, and equipping of the actual recovery facilities.

1.3.7.3 FUEL FACILITIES

This element includes fuel production facilities, storage and handling facilities, transportation, and delivery and safety facilities for both the fuel and the oxidizer. Also included are the facilities for fuels used in the various orbital transfer facilities.

1.3.7.4 LOGISTICS SUPPORT

This element includes the land, buildings, and handling equipment for the receiving, inspection, and storage and packaging of all payloads to be launched except for fuels and oxidizers.

1.3.7.5 OPERATIONS

This element includes the planning, development, and conduct of operations at the ground support facilities. It includes both the direct and support personnel and the expendable maintenance supplies required for the ground support facilities operation and maintenance.

1.4 GROUND RECEIVING STATION

This element includes the land, facilities, and equipment that comprise the ground subsystems utilized to receive the radiated microwave power beam and to provide the power at the required voltage and type of current for entry into the national power grid. Also included are the equipment and facilities necessary to provide operational control over the satellite.

1.4.1 SITE AND FACILITIES

This element encompasses the site and facilities for the ground receiving station system which includes the rectenna, grid interface, and satellite control subsystems. Included are the land, site preparation, roads, fences, utilities, lightning protection, buildings, and maintenance equipment required to house and support the other ground station subsystems.

1.4.2 RECTENNA SUPPORT STRUCTURE

This element includes the hardware, materials (steel and concrete), and assembly operations necessary to erect the physical support for the rectenna array elements of WBS No. 1.4.3.

1.4.3 POWER COLLECTION

This element includes the antenna array elements associated with the actual reception and rectification of the microwave radiation. These elements are in series and parallel as required to deliver the required output voltage and

current. Also included are those components that accept the dc power from the array elements and route, control, convert, and switch this power for delivery to power conversion stations of the grid interface.

1.4.4 CONTROL

This element includes the hardware that will be used to monitor and control the satellite from the ground. Included are telemetry, tracking, communications, monitoring of microwave beam characteristics, computing phase corrections, and providing frequency standard signals for the satellite. Functional requirements provide for signal conditioning, formatting, software, computations, and signal routing.

1.4.5 GRID INTERFACE

This element includes the power conversion equipment that receives the electrical power from the power collection subsystem and conditions/converts it to a high voltage dc or ac power acceptable for input into the national power grid. Also included are those components necessary to route, control, and switch this power into the national power grid.

1.4.6 OPERATIONS

This element includes the planning, development, and conduct of operations at the ground receiving station. It includes both the direct and support personnel and the expendable maintenance supplies required for the ground station operation and maintenance.

1.5 MANAGEMENT AND INTEGRATION

This element includes all efforts and material required for management and integration functions at the systems level and program level. It encompasses the following functions:

a) Program Administration
b) Program Planning and Control
c) Contracts Administration
d) Engineering Management
e) Manufacturing Management
(f) Support Management
(g) Quality Assurance Management
(h) Configuration Management
(i) Data Management
(j) Systems Engineering and Integration

This element sums all direct efforts required to provide management control, including planning, organizing, directing, and coordinating the project to ensure that overall project objectives are accomplished. These efforts overlay the functional work areas (e.g., engineering, manufacturing, etc.) and assure that they are properly integrated. This element also includes the efforts required in the coordination, gathering, and dissemination of management information. Also included are the engineering efforts related to the establishment and maintenance of a technical baseline for a system by generation of system configuration parameters, criteria, and requirements. It includes requirements analysis and integration, system definition, system test definition, interfaces, safety, reliability and maintainability. It also includes those efforts required to monitor the system development and operations to ensure that the design conforms to the baseline specifications.

1.5 MASS CONTINGENCY

This element provides for a cost contingency to offset the variability of mass estimates/determinations on items of SPS hardware/software as planned for deployment in space. This would potentially involve the WBS categories of 1.1, Satellite; 1.2, Space Construction and Support; and 1.3, Transportation.

APPENDIX B

SATELLITE POWER SYSTEM COST ESTIMATES

SOLAR PHOTOVOLTAIC CELLS
CONCENTRATION RATIO (CR)—2 EFF.
THREE-TROUGH PLANAR
END-MOUNTED ANTENNA(S)

APPENDIX B
SATELLITE POWER SYSTEM
COST ESTIMATES

B.0 INTRODUCTION

This appendix contains results of extensive analyses to identify cost estimates for hardware and activities of the Satellite Power System (SPS program. It is divided into sections covering a description of SPS configurations and technical characteristics, details on study guidelines, a discussion of costing methodology, line item cost summaries, and supporting detail on the analyses and elements of cost in each area.

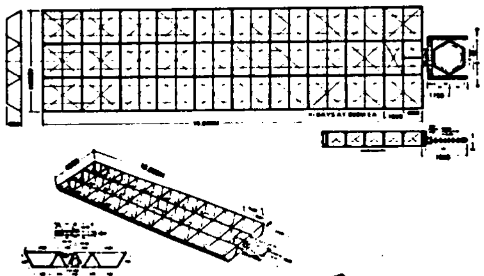
In order to promote a complete and understandable comparison of SPS costs, and to maintain a compatible economic and programmatic reference, the SPS work breakdown structure of Appendix A was used as a framework for cost and programmatic definition. This has provided for the development of costs at each of the intersects identified on the WBS matrix of Figure B-1. Approximately 300 line items were identified within each category of DDT&E, theoretical first SPS, SPS investment, and operations as applied to the SPS concepts studied.

B.1 SPS CONCEPTS

Five SPS concepts were costed in detail during the Exhibit D contract activity. Each concept utilized a satellite configuration from one of the two "families" shown in Figure B-2. The three-trough planar configurations have masses averaging 32.7×10^6 kg versus 18.5×10^6 kg for the reflector/sandwich configurations. Other differences between these families are variable power output at the utility interface, concentration ratios, and relative mass per kW at the utility interface.

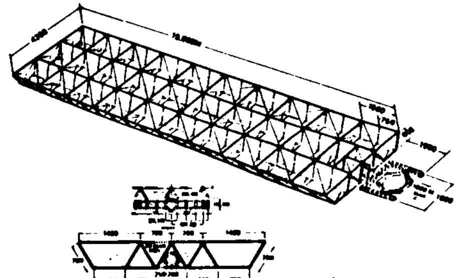
HARDWARE AND ACTIVITIES	PROGRAM PHASE: DDT&E	THEORETICAL FIRST SPS	SPS INVESTMENT PER SATELLITE	OPERATIONS
1.0 SATELLITE POWER SYSTEM				
1.1 SATELLITE				
1.1.1 ENERGY CONVERSION				
1.1.2 POWER TRANSMISSION				
1.1.3 INFORMATION MANAGEMENT & CONTROL				
1.1.4 ATTITUDE CONTROL AND STATIONKEEPING				
1.1.5 COMMUNICATIONS				
1.1.6 INTERFACE (ENERGY CONVERSION/ POWER TRANSMISSION)				
1.1.7 SYSTEMS TEST				
1.1.8 GSE				
1.1.9 PILOT PLANT				
1.2 SPACE CONSTRUCTION AND SUPPORT				
1.2.1 CONSTRUCTION FACILITIES				
1.2.2 LOGISTICS SUPPORT FACILITIES				
1.2.3 O&M SUPPORT FACILITIES				
1.3 TRANSPORTATION				
1.3.1 SPS VTO/HL HLLV				
1.3.2 COTV				
1.3.3 STS PLV				
1.3.4 POTV				
1.3.5 PM				
1.3.6 IOTV				
1.3.7 GROUND SUPPORT FACILITIES				
1.4 GROUND RECEIVING STATION				
1.4.1 SITE AND FACILITIES				
1.4.2 RECTENNA SUPPORT STRUCTURE				
1.4.3 POWER COLLECTION				
1.4.4 CONTROL				
1.4.5 GRID INTERFACE				
1.4.6 OPERATIONS				
1.5 MANAGEMENT AND INTEGRATION				

Figure B-1. SPS Work Breakdown Structure



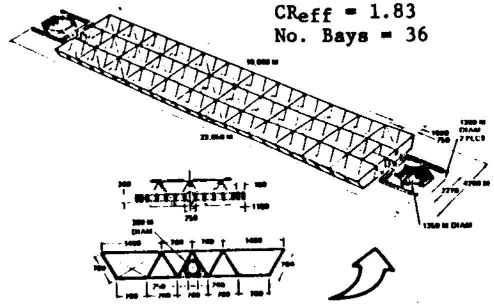
CR_{eff} = 1.83
No. Bays = 30
Mass = 31.63x10⁶ kg
Power at Utility I/F = 5.00 GW
Specific Mass = 6.33 kg/kW

SPS CR-2 REFERENCE CONFIGURATION (3-TROUGH/PLANAR/KLYSTRON)



CR_{eff} = 1.83
No. Bays = 30
Mass = 26.7×10^6 kg
Power at Utility I/F = 5.6 GW
Specific Mass = 4.77 kg/kW

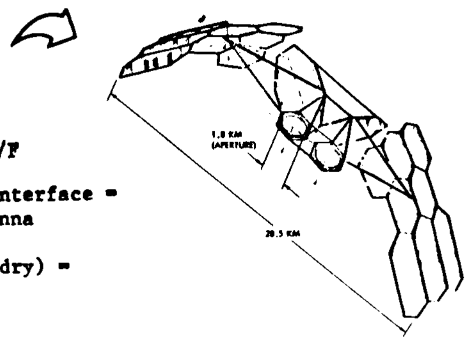
SPS CR-2 MAGNETRON CONFIGURATION (3-TROUGH/PLANAR)



CR_{eff} = 1.83
No. Bays = 36

No. Panels = 72
Solar Array Power Generated = 11.46 GW
Power at Utility = 5.22 GW
Sp. Mass = 7.66 kg/kW_{util}

SPS CR-2 SOLID-STATE CONFIGURATION (3-TROUGH/PLANAR/DUAL END-MOUNTED ANTENNA)

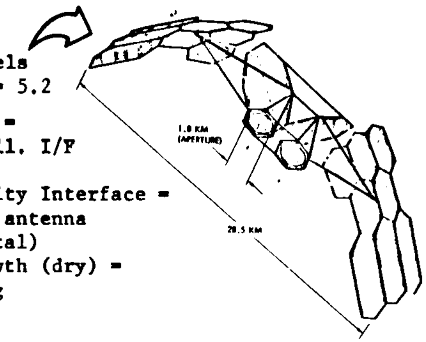


GaAs Solar Panels
Effective CR = 5.2

Specific Mass = 8.48 kg/kW Util. I/F

Power at Utility Interface = 1.21 GW per antenna (2.42 GW total)
Mass with Growth (dry) = 20.53×10^6 kg

SOLID-STATE GaAs SANDWICH CR-5 CONFIGURATION (DUAL REFLECTORS/ANTENNAS)



MBG Solar Panels
Effective CR = 5.2

Specific Mass = 5.35 kg/kW Util. I/F

Power at Utility Interface = 1.53 GW per antenna (3.06 GW total)
Mass with Growth (dry) = 16.39×10^6 kg

SOLID-STATE GaAlAs MBG SANDWICH CR-5 CONFIGURATION (DUAL REFLECTORS/ANTENNAS)

Figure B-2. Rockwell SPS Satellite Concepts - 1980

The SPS reference satellite configuration consists of a three trough-planar solar cell array with concentrators utilizing klystron tubes for powering the microwave transmission array. This satellite transmits microwave energy to a single receiving antenna at a ground based location where it is converted into electrical power for entry into the utility grid.

This same solar array approach is utilized in a second concept, excepting those design modifications that accommodate the characteristics and requirements of a magnetron tube used for the generation of microwave energy. The specific mass of the configuration is 4.77 kg/kW with a total mass of 26.7x10 kg including growth. GaAs solar cell power capabilities dictate the overall length of 16,900 m.

A third configuration utilizes dual end-mounted solid state antennas that provide one-half the total power output of the satellite (3.68 GW per antenna). The specific mass of this satellite is 7.66 kg/kW based on calculated power at the utility interface.

The solid-state sandwich configurations of the second family consist of dual mirror reflector surfaces that focus the sun's energy upon solar cell blankets forming a part of the antenna array sandwich of the microwave generation system. The primary mirror is rotated about the satellite's reflector axis so that the dual spacetennas remain locked on the earth based receiving antennas. Specific mass of these concepts vary from 8.48 kg/kW to 5.35 kg/kW due to the type of solar cell used.

B.2 COSTING GROUND RULES AND GUIDELINES

Guidelines and assumptions used in the development of cost and programmatic aspects of this study acknowledge study parameters and criteria, the availability of supporting programs, SPS development schedules, and provide a basis for the uniform development of cost and programmatics.

1. Key dates of program planning:

   1981-1986 Ground-Based Exploratory Development (Research and Development)
   1981-1987 Key Technology Advancement Activities
   1990 Decision Point for SPS Commercialization (Phase C/D)
   2000 SPS Initial Operational Capability

2. Report costs at WBS levels in terms of:

   - SPS development costs and TFU (theoretical first unit) costs
   - Average initial capital investment cost per satellite
   - Replacement capital investment (RCI) cost and operations and maintenance (O&M) cost per satellite per year

3. Cost estimates to be projected in 1979 dollars.

4. Maximum use shall be made of cost data from past SPS studies and associated government/contractor data files.

5. SPS options shall provide a 300 GW capability at the utility interface with a total capacity of 300 GW by year 2030.

6. Overall SPS lifetime will be 30 years with minimum maintenance and no salvage value or disposition costs.

7. Complete construction and assembly will occur at geosynchronous orbit.

8. Calculations are based on 0% launch losses.

9. Program management and SE&I (management and integration) are costed at 5% of all other Level 2 costs.

10. 25% mass contingency is costed as a 15% cost contingency on SPS WBS items of the satellite (1.1) and space construction and support (1.2). Space transportation (1.3) masses include a 25% contingency on mass in lieu of the 15% cost contingency.

11. Supporting program considerations:
    - Space Shuttle
    - Interim Upper Stage
    - Solar Electric Power System
    - Personnel OTV

B.3 COSTING METHODOLOGY

The approach followed in developing cost estimates for the SPS program was based on the maximum use of results from the current study, a reliance on accomplishments of past contract activity, and the use of other contract and company sponsored work. The calculation of cost estimates and the organization/reporting of cost data was accomplished through the use of Rockwell's flexible Cost/Risk Analysis Computer Program as adapted for the SPS. This computer program has been continuously updated to incorporate expanded and lower level indentures of SPS-WBS definition including those revisions required as a result of design variations within the five concepts.

Since starting work on Exhibit D, the data base of existing and proved CER's was expanded by special analyses of technical design definitions to obtain cost estimates of SPS assemblies and components. This included analyses on satellite secondary structures and the klystron, magnetron, and solid state designs of the microwave generation/transmission system.

As to the computer program and cost calculations, there are a series of equations that deal with four basic types of cost accounts and phases of the program - DDT&E, initial capital investment, replacement capital investment, and operations and maintenance.

The DDT&E equation (CD) estimates the cost of the design, development, and test/evaluation of WBS line items for the satellite, space construction and support, transportation, and ground receiving station, plus management and integration support. Management and integration are costed as a separate line item at 5% of all other level two costs of the WBS. Because of the gross nature of the level of information/definition on systems test and GSE (ground support equipment), the cost of system test hardware, and system test operations, has been assumed to be one-half of the satellite system average unit investment costs. A 10% factor of satellite DDT&E is used for GSE.

Appropriate inputs for the DDT&E CERs are the applicable total system mass, area, or power. A development factor is provided in the equation (DF) to adjust the cost to reflect only that portion of the total system mass, area or power considered necessary for development of the complete system where it is not required to develop the total mass, area or power. The CD cost equation also allows for the application of a complexity factor (CF) to adjust the cost results when it is determined that the item being estimated is either more or less complex than the CER base data.

Capital investment (ICI) cost equations estimate the initial capital investment cost of hardware items as a function of their mass, area or power. The ICI cost equation is expressed in four different forms—CLRM, CTFU, CTB, and CIPS. The CLRM (cost of lowest repeating module) equation requires that the input correspond to the mass, area or power of the lowest repeating module (M). This is necessary because of the physical scale of the SPS and the production quantities required for many of the hardware elements. It is not reasonable to estimate the SPS initial capital investment cost as a historical function of the entire SPS mass, area or power. Instead, it is desirable to cost the number of repeating modules required per satellite to establish the satellite theoretical first-unit cost (TFU), and to input the satellite TFU cost into a progress (learning) function for the quantity of satellites required to calculate the average unit cost (CTB - cost to build). This calculation involves two steps in the cost equations. The first step (CLRM) is simply the portion of the equation which estimates the theoretical first repeating module cost as discussed above. The second step (CTFU) has the progress function incorporated into the equation for the quantity of repeat modules required for the first satellite. It automatically takes into account the progress over production quantities required when calculating the cost to build an average unit over the total option quantity. This CTB calculation is then the basis of CIPS (cost of investment per system), where the number of units to construct a satellite option are divided by the option quantity and then multiplied by the CTB. In some initial investment cost equations, such as those of SPS transportation, the space vehicle has a service life that is greater than that needed to construct a single satellite. The CIPS calculation provides accurate system cost assessments on an individual SPS basis.

At the current level of SPS definition, it was difficult to decide just what is a repeating module. It is often impossible to know with any certainty just what portion of the total mass is appropriate to run through the equation as a module. It is just as difficult to identify how many distinct types or designs of modules will be required for any subsystem or assembly. In such cases, the study simply assumed a module mass (or area or power) based on engineering best judgment.

Replacement capital investment (CRCI) CERs simply provide for the multiplication of the annual spares fraction (R) of each system by that system's cost to build in order to arrive at an RCI cost per satellite per year. An "R" factor was identified by dividing the number of equivalent satellite replacements over 30 years with a value equal to the number of satellites (satellite option) times 30 years.

An objective of the cost analysis task involving replacement capital investment was to segregate costs associated with replacement capital and

operations/maintenance expenditures that occur before or after SPS-IOC (initial operations capability). A new programming feature was therefore, added to the Rockwell computer program that acknowledges this calculation and presents pre and post-IOC expenditures over the life of each SPS.

Operations and maintenance costs (CO&M) were estimated in terms of O&M cost per satellite per year. These costs include those expenditures incurred in day-to-day operations beginning with SPS initial operating capability (IOC) and continuing over the life of each satellite. They consist of wages of operations and maintenance personnel, minor repairs and adjustments to systems to maintain an ordinarily efficient operating condition, expendables and consumables, launch costs for delivery and transfer of on-orbit personnel and cargo resupply of expendables and consumables, etc.

The cost methodology seeks to account for five separate effects which influence SPS cost. These are scaling, specification requirements, complexity, the degree of automation, and production progress. Scaling refers to the relationship in cost between items varying in size, but similar in type. Economies of scale usually assure that such a relationship will not be strictly linear, but rather as size increases, cost per unit of size will decrease. The slope of this relationship is reflected by the equation exponent which results from the regression analysis of the data used to develop the cost estimating relationship.

Specification requirements have been accounted for by normalizing the CER data base to manned spacecraft specification levels using factors from the RCA Price Model.[1] From that model, an average cost factor to adjust MILSPEC to manned spacecraft is around 1.75 for DDT&E and 1.6 for production cost. Under the assumption that some relaxation of Apollo-type specifications can be made for the SPS, a factor of 1.5 was assumed for both DDT&E and production cost. Furthermore, it was assumed that a factor of 3.0 would adjust commercial specifications to SPS requirements. Therefore, military or commercial cost data used in the CERs were adjusted upward by factors of 1.5 and 3.0, respectively.

The cost equations allow a complexity factor input to adjust the cost result when it is determined that the item being estimated is either more or less complex than the listed CER data base.

The degree of automation is accounted for in certain cost equations through an adjustment to the CER coefficient by the tooling factors given in Table B-1. The effect of tooling is dependent upon the annual production rate. Higher production rates allow harder tooling and, thus, effect cost reductions. The tooling factors are used only on those CERs which are based on historical aerospace programs with limited annual production rates. Tooling factors are not used on those CERs which are based on data already reflecting automated production techniques (e.g., the commercial electronics data for the microwave antenna CER).

[1]Equipment Specification Cost Effect Study, Phase II Final Report, Nov. 30, 1976, by RCA Government Systems Division.

Table B-1. SPS Tooling Factors

AVERAGE ANNUAL PRODUCTION RATE (AAPR)	TOOLING FACTOR (TF)	PROGRESS FRACTION (ø)
1-2	1-0	0.80
3-5	0.9	0.80
6-9	0.8	0.80
10-19	0.7	0.85
20-39	0.6	0.85
40-69	0.5	0.85
70-109	0.4	0.85
110-159	0.3	0.90
160-219	0.2	0.90
220-999	$(AAPR)^{-0.35}$	0.90
1000-9999	$(AAPR)^{-0.35}$	0.95
10,000	$(AAPR)^{-0.35}$	0.98

The decreasing cost effects of progress due to production process improvements or direct labor learning are accounted for through standard progress functions. Many SPS components will be mass produced in a capital intensive manner and will experience little labor learning. Other SPS hardware items, however, will be produced at very low annual rates, much in the labor-intensive manner of historical spacecraft programs, and therefore would experience learning. (Technically distinguishable from learning, but still predictable with the same form of exponential function, are the effects of production process improvement. In this model, when progress functions are used, they are meant to account for both of these effects.) A constant relationship has been assumed between the progress fraction and the annual production rate as given in Table B-1.

As required by costing ground rules and assumptions, all CERs are in terms of 1979 dollars. The study did assume 1990 technology and 1990 supply/demand conditions which, in some cases, resulted in differential (non-general) price inflation or deflation between 1979 and 1990 being included in the CERs. Specifically, it was assumed that composite raw material prices and some electronic component prices will decrease relative to general prices while aluminum coil stock prices will increase relative to general prices. Such effects are allowed for by the CERs, but only to the extent that the expected price changes differ from expected general price changes. The CERs affected are the antenna structure CER, the power source structure CER, and the microwave antenna CER.

Definitions of SPS cost model terms and equation abbreviations are presented in Table B-2. Figure B-3 illustrates the format of cost data sheets developed for each WBS line item of the particular concept as produced by the SPS dedicated computer program.

Table B-2. Definitions of SPS Computer Cost Model Terms

C	=	COST IN MILLIONS OF 1979 DOLLARS
CD	=	DDT&E COST
CDCER	=	DDT&E COST ESTIMATING RELATIONSHIP (CER)
CDEXP	=	DDT&E SCALING EXPONENT
CER	=	COST ESTIMATING RELATIONSHIP
CF	=	COMPLEXITY FACTOR
CICER	=	INITIAL CAPITAL INVESTMENT COST ESTIMATING RELATIONSHIP (CER)
CIEXP	=	INITIAL CAPITAL INVESTMENT COST SCALING EXPONENT
CTB	=	COST TO BUILD AN ITEM
CIPS	=	INVESTMENT COST PER SATELLITE POWER SYSTEM
CLRM	=	LOWEST REPEATING MODULE COST
CO&M	=	OPERATIONS AND MAINTENANCE COST PER SPS PER YEAR
CRCI	=	REPLACEMENT CAPITAL INVESTMENT COST PER SPS PER YEAR
CTFU	=	THEORETICAL FIRST UNIT COST
DDT&E	=	DESIGN, DEVELOPMENT, TEST AND EVALUATION
DF	=	DEVELOPMENT FRACTION
E	=	1.0 + LOG (PHI) ÷ (2.0)
ICI	=	INITIAL CAPITAL INVESTMENT
INV. PER SAT.	=	AVERAGE UNIT INVESTMENT COST (2 THRU N)
M	=	MASS, POWER, AREA OF LOWEST REPEATING MODULE
#RM	=	NUMBER OF REPEATING MODULES
OPS	=	OPERATIONS
O&M	=	OPERATIONS AND MAINTENANCE COST PER SPS PER YEAR
PRE-IOC	=	BEFORE SPS INITIAL OPERATIONAL CAPABILITY
POST-IOC	=	AFTER SPS INITIAL OPERATIONAL CAPABILITY
PHI	=	PROGRESS FRACTION
R	=	ANNUAL SPARES FRACTION
RCI	=	REPLACEMENT CAPITAL INVESTMENT COST PER SPS PER YEAR
T	=	TOTAL (MASS, POWER, AREA) PER SYSTEM
TF	=	TOOLING FACTOR
TFU	=	THEORETICAL FIRST UNIT
Z1	=	TFU REQUIREMENT
Z2	=	SPS OPTION QUANTITY
Z3	=	TOTAL SPS REQUIREMENT PER OPTION
Z4	=	ITEMS NEEDED TO CONSTRUCT SATELLITE OPTION
Z5	=	ITEMS NEEDED FOR O&M OF THE SATELLITE OPTION
Z6	=	RATIO OF Z4 to Z5 FOR PRE-IOC AND POST-IOC CALCULATIONS

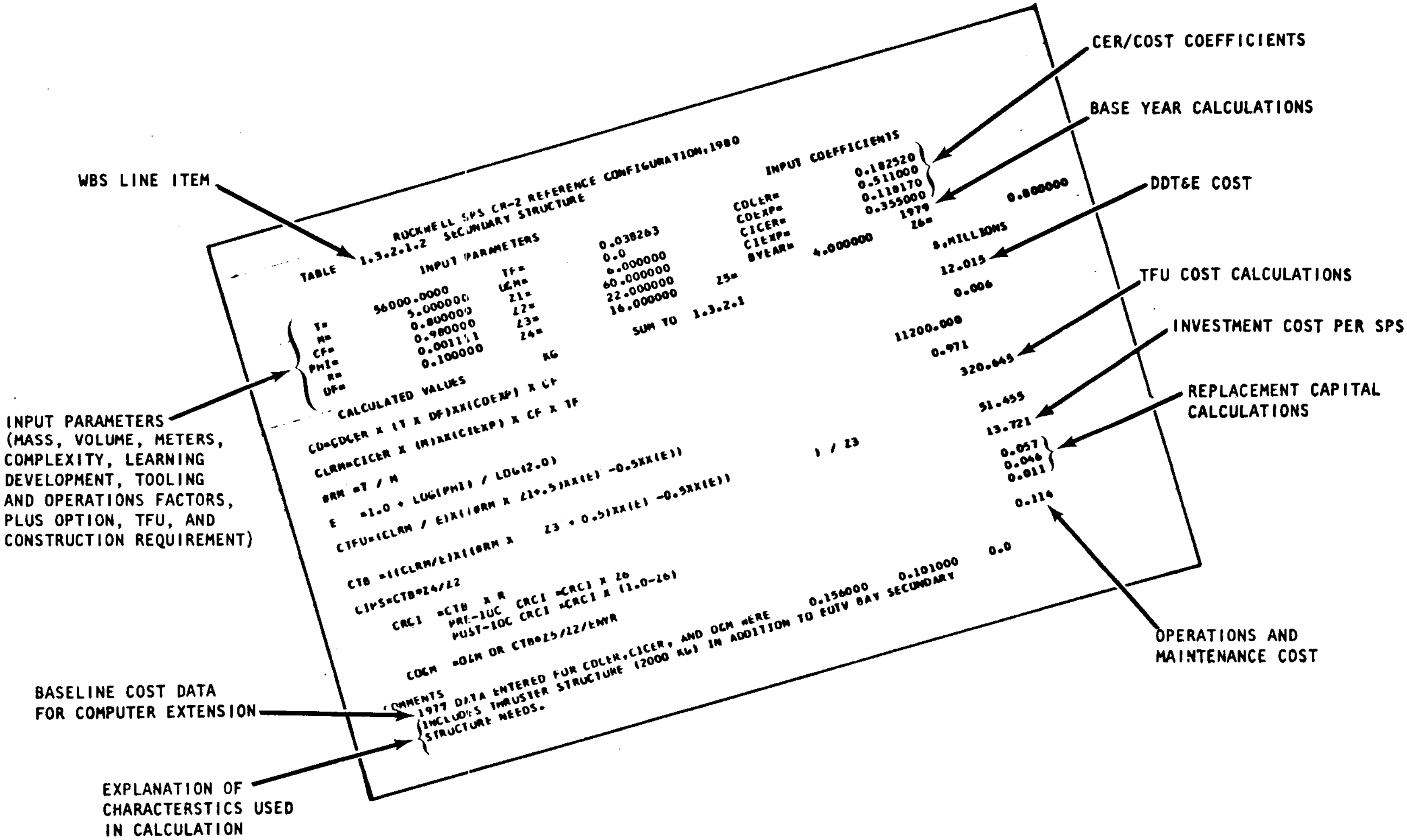


Figure B-3. SPS Computer Cost Printout

B.4 SPS PROGRAM COST BREAKDOWNS

A summary of SPS estimates presented in this section emphasizes costs of the updated Rockwell SPS reference three-trough/planar/klystron concept where line item detail is presented for DDT&E, TFU, investment per SPS, and RCI/O&M phases.

An overall comparison of five SPS concepts was developed during the study as identified in Table B-3. Option quantities and power output at the utility interface are consistent with the provision to establish a 300 GW capability at 30 years. DDT&E values represent non-recurring front-end program costs estimated for each concept. TFU costs represent hardware, software, and services needed to build the first unit. Investments per satellite and RCI/O&M estimates during construction operations equal the average SPS cost based on the procurement option. Post-IOC operations cost is the annual amount required to maintain each SPS system after it becomes operational. Installation costs per kW are shown in the last column.

Table B-3. SPS Concept Comparisons

SPS CONCEPT	SPS OPTION QUAN.	1979 DOLLARS (BILLIONS)					
		DDT&E	TFU	INVESTMENT PER SATELLITE	CONSTRUCTION OPERATIONS (RCI/O&M)	POST-IOC OPERATIONS ($/SAT/YR)	INSTALLATION COST $/KW
REFERENCE UPDATE GaAs PLANAR/KLYSTRON ($5.00\ GW_{UTIL}$)	60	33.6	53.6	12.7	2.3	0.14	$3000
				15.0			
THREE-TROUGH GaAs PLANAR-MAGNETRON ($5.60\ GW_{UTIL}$)	54	31.7	52.0	11.8	2.2	0.13	$2500
				14.0			
THREE-TROUGH GaAs PLANAR-SOLID STATE ($5.22\ GW_{UTIL}$)	58	35.0	56.0	15.0	2.8	0.14	$3400
				17.8			
DUAL REFLECTORS GaAs-SANDWICH ($2.42\ GW_{UTIL}$)	125	32.7	57.3	7.4	1.5	0.08	$3680
				8.9			
DUAL REFLECTORS MBG-SANDWICH ($3.06\ GW_{UTIL}$)	98	32.8	55.7	7.8	1.3	0.08	$2975
				9.1			

Cost estimates have been based on technical characteristics and design definitions developed during the study. A summary of DDT&E and first unit costs are presented in Table B-4 for space and ground segments of the reference SPS configuration. These same elements of the program are listed in Table B-5 as they apply to the investment per SPS.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION, 1980
TABLE B-4 SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DDT&E	DEVELOPMENT TFU	TOTAL
1	SATELLITE POWER SYSTEM (SPS) PROGRAM	33589.691	53646.430	87236.062
1.1	SATELLITE SYSTEM	7799.059	9811.328	17610.387
1.2	SPACE CONSTRUCTION & SUPPORT	8564.035	10757.824	19321.859
1.3	TRANSPORTATION	13154.137	23334.477	36488.613
1.4	GROUND RECEIVING STATION	135.368	4249.754	4385.121
1.5	MANAGEMENT AND INTEGRATION	1482.630	2407.669	3890.299
1.6	MASS CONTINGENCY	2454.463	3085.372	5539.832

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION, 1980
TABLE B-5 SATELLITE POWER SYSTEM (SPS) PROGRAM AVERAGE COST

WBS #	DESCRIPTION	INV PER SAT	** OPS COST PER SAT PER YEAR ** RCI	O&M	TOTAL OPS
1	SATELLITE POWER SYSTEM (SPS) PROGRAM	12742.617	145.772	77.249	223.022
1.1	SATELLITE SYSTEM	4978.184	33.025	0.720	33.745
1.2	SPACE CONSTRUCTION & SUPPORT	209.874	19.465	19.341	38.806
1.3	TRANSPORTATION	1989.518	78.521	17.419	95.940
1.4	GROUND RECEIVING STATION	4217.105	0.321	33.225	33.547
1.5	MANAGEMENT AND INTEGRATION	569.734	6.567	3.535	10.102
1.6	MASS CONTINGENCY	778.208	7.874	3.009	10.883

As was mentioned, RCI and O&M costs have been segregated into pre-IOC and post-IOC categories. Pre-IOC tabulations were calculated on an annual basis as presented in Table B-6. The total pre-IOC value per SPS would require multiplication by 30 years. Post-IOC operations costs are presented in Table B-7 for the reference configuration on an annual basis. A summary of costs on all five SPS concepts—including pre- and post-IOC values, was shown in Table B-3.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION, 1980
TABLE B-6 SATELLITE POWER SYSTEM (SPS) PROGRAM PRE-IOC COSTS

WBS #	DESCRIPTION	AVERAGE INV PER SAT	****PRE-IOC ********* OPS COST PER SAT/YR RCI-PRE	O&M-PRE	TOTAL PRE-IOC
1	SATELLITE POWER SYSTEM (SPS) PROGRAM	12742.617	71.944	6.104	78.048
1.1	SATELLITE SYSTEM	4978.184	0.0	0.0	0.0
1.2	SPACE CONSTRUCTION & SUPPORT	209.874	4.331	3.713	8.044
1.3	TRANSPORTATION	1989.518	63.481	0.0	63.481
1.4	GROUND RECEIVING STATION	4217.105	0.087	1.570	1.657
1.5	MANAGEMENT AND INTEGRATION	569.734	3.395	0.264	3.659
1.6	MASS CONTINGENCY	778.208	0.650	0.557	1.207

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION, 1980

TABLE B-7 SATELLITE POWER SYSTEM (SPS) PROGRAM POST-IOC COSTS

WBS #	DESCRIPTION	***POST-IOC ********* OPS COST PER SAT/YR RCI-POST	O&M-POST	TOTAL POST-IOC
1	SATELLITE POWER SYSTEM (SPS) PROGRAM	73.828	71.146	144.974
1.1	SATELLITE SYSTEM	33.025	0.720	33.745
1.2	SPACE CONSTRUCTION & SUPPORT	15.134	15.628	30.762
1.3	TRANSPORTATION	15.039	17.419	32.459
1.4	GROUND RECEIVING STATION	0.234	31.656	31.890
1.5	MANAGEMENT AND INTEGRATION	3.172	3.271	6.443
1.6	MASS CONTINGENCY	7.224	2.452	9.676

Relative distributions of cost for the Rockwell reference concept are shown in Figure B-4. Transportation systems dominate DDT&E and first-unit cost by contributing to over 40% of each cost estimate. However, in the case of the TFU, it is known that these costs cover system elements with a service life that is capable of building more than one SPS. Whereas, average investment costs and construction operations (RCI/O&M) dollars for the reference

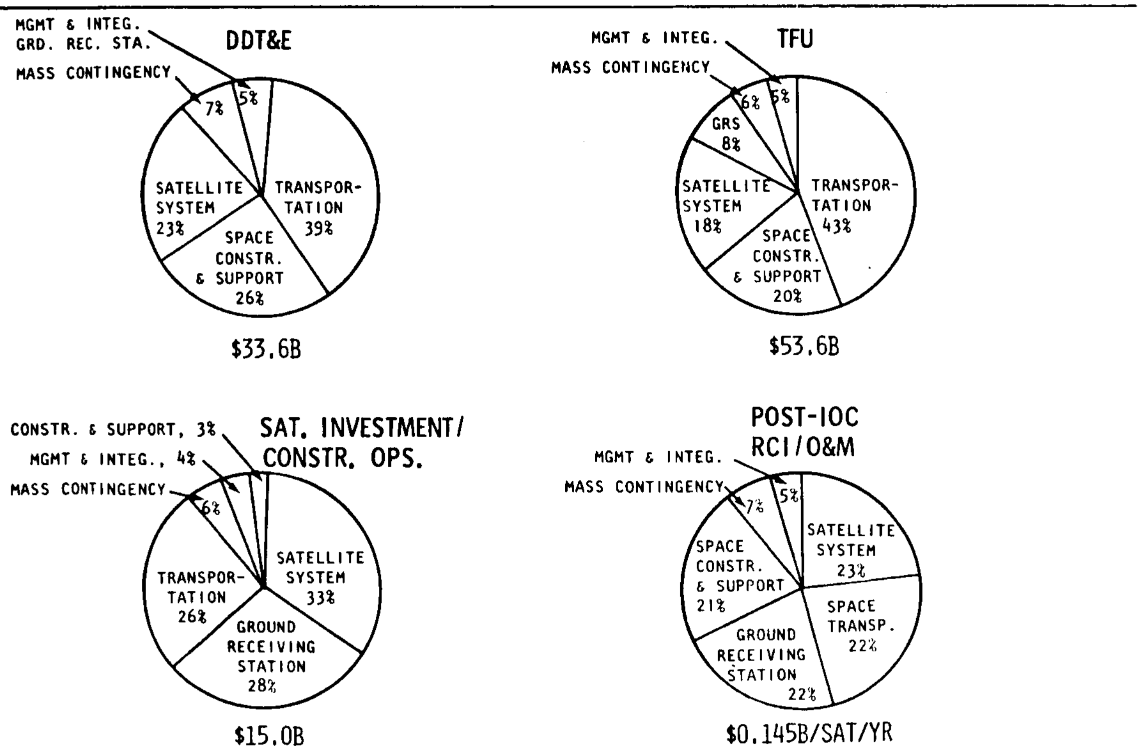


Figure B-4. Rockwell Reference Planar/Klystron Concept (1980 Exhibit D—1979 Dollars)

concept show that the satellite, GRS, and transportation system elements each comprise about 30% of the total.

B.4.1 DEVELOPMENT COST (DDT&E) AND THEORETICAL FIRST UNIT (TFU)

Total program DDT&E and TFU cost for a first full-up 5-GW SPS system is $87.2 billion. The DDT&E of $33.6 billion and the $53.6 billion for the TFU are itemized by SPS WBS line item in a subsequent table. Detailed DDT&E cost breakdowns show that 65% of the DDT&E cost is identifiable to transportation and space construction/support systems.

In view of the physical size of the satellite and supportive subsystems and the large quantities required for certain parts and components, it was not considered reasonable to estimate the DDT&E costs entirely as a function of total mass, area, or power per subsystem—which is generally the method; instead, it was considered desirable to determine DDT&E costs by application of a development factor (DF). In general, the DF was applied on the basis of a particular system/component in conjunction with the engineering staff and as related to the program development scenario and the usage/availability of the system when needed. For example, the EOTV pilot plant and test article is required early in the program for SPS verification and proof of concept. This unit will be built first and DDT&E on many components will be required before items can be made available. (For example, the structure, concentrators, solar cells, power distribution, and supporting SPS systems will afford design verifications nearly identical to those of the full-up SPS satellite.) As a result, a 1.0 DF was used on components of the test article; whereas on later usages of these systems, such as on similar systems of the satellite itself, a reduced factor was applied in recognition of the completed DDT&E effort. This logic was also followed in other areas of SPS program cost analysis.

DDT&E and TFU cost breakdowns are shown in Table B-8. The TFU listing reflects a somewhat different makeup of costs when compared to the DDT&E costs. TFU estimates of $53.6 billion include the full dollar assessment for an early pilot plant, an initial satellite and ground receiving station, space transportation fleets, the LEO, SCB, and support assembly equipment, and the facilities needed to establish a 5-GW SPS operational capability. This means that the TFU cost includes elements with a service lifetime capable of building more than one SPS system. In this regard, analysis has shown that transportation and space construction and support equipment represent the largest portion of total TFU costs. However, it is these same systems that will be used to construct additional satellites.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION, 1980

TABLE B-8. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DEVELOPMENT DDT&E	DEVELOPMENT TFU	TOTAL
1	SATELLITE POWER SYSTEM (SPS) PROGRAM	33589.691	53646.430	87236.062
1.1	SATELLITE SYSTEM	7799.059	9811.328	17610.387
1.1.1	ENERGY CONVERSION - SATELLITE	137.259	2554.026	2691.285
1.1.1.1	STRUCTURE	82.870	213.410	296.280
1.1.1.1.1	PRIMARY STRUCTURE	55.568	54.288	109.856
1.1.1.1.2	SECONDARY STRUCTURE	19.906	154.716	174.622
1.1.1.1.3	MECHANISMS	7.396	4.406	11.802
1.1.1.2	CONCENTRATORS	0.0	93.066	93.066
1.1.1.3	SOLAR BLANKETS	20.254	2035.508	2055.762
1.1.1.4	POWER DIST. & CONDITIONING	34.135	150.382	184.517
1.1.1.4.1	SWITCH GEAR & REGULATORS - E.C.	3.873	106.978	110.851
1.1.1.4.2	LO-VOLTAGE CONVERTERS - E.C.	1.362	4.202	5.563
1.1.1.4.3	CONDUCTORS & INSULATION	7.320	11.209	18.528
1.1.1.4.4	SLIP RINGS	8.648	25.999	34.648
1.1.1.4.5	BATTERIES	6.511	0.317	6.829
1.1.1.4.6	BATTERY PD&C	6.421	1.677	8.098
1.1.1.5	THERMAL CONTROL	0.0	0.0	0.0
1.1.1.6	MAINTENANCE	0.0	61.660	61.660
1.1.1.6.1	MAINTENANCE - FREE FLYERS	0.0	34.279	34.279
1.1.1.6.2	MANNED MANIPULATOR	0.0	22.467	22.467
1.1.1.6.3	TRACKS & ACCESS WAYS	0.0	4.914	4.914
1.1.2	POWER TRANSMISSION - SATELLITE	1041.111	2568.322	3609.432
1.1.2.1	STRUCTURE	36.067	215.729	251.796
1.1.2.1.1	PRIMARY STRUCTURE	3.632	1.345	4.977
1.1.2.1.2	SECONDARY STRUCTURE	23.561	213.118	236.679
1.1.2.1.3	MECHANISMS (TRUNNIONS)	8.874	1.266	10.140
1.1.2.2	TRANSMITTER SUBARRAYS - KLYSTRONS	129.306	1580.665	1709.971
1.1.2.2.1	KLYSTRON MPT & RS DDT&E	129.306	0.0	129.306
1.1.2.2.2	WAVE GUIDE	0.0	38.639	38.639
1.1.2.2.3	HEAT PIPES -THERMAL	0.0	333.757	333.757
1.1.2.2.4	KLYSTRON POWER MODULE ELEMENT	0.0	304.621	304.621
1.1.2.2.5	PHASE SHIFTERS	0.0	166.307	166.307
1.1.2.2.6	PHASE CONTROL ELECTRONICS	0.0	144.703	144.703
1.1.2.2.7	POWER DIVIDERS & COMBINERS	0.0	23.031	23.031
1.1.2.2.8	MW SYSTEM INTEGRATION	0.0	569.608	569.608

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION, 1980

TABLE B-8. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DDT&E	DEVELOPMENT TFU	TOTAL
1.1.2.3	POWER DIST. & CONDITIONING	26.852	471.514	498.366
1.1.2.3.1	SWITCH GEAR & REGULATORS	4.014	108.028	112.042
1.1.2.3.2	HI-VOLTAGE CONVERTERS	7.382	310.012	317.395
1.1.2.3.3	LO-VOLTAGE CONVERTERS	2.392	1.338	3.730
1.1.2.3.4	CONDUCTORS & INSULATION	5.232	3.618	8.849
1.1.2.3.5	BATTERIES	0.0	14.901	14.901
1.1.2.3.6	BATTERY P&C	7.832	33.618	41.450
1.1.2.4	THERMAL CONTROL - INSULATION	14.174	170.118	184.292
1.1.2.5	CONTROL - PHASE REFERENCE	0.901	51.328	52.229
1.1.2.5.1	REFERENCE FREQUENCY GENERATOR	0.117	0.117	0.234
1.1.2.5.2	DIST. SYSTEM, COAXIAL CABLE	0.702	42.120	42.822
1.1.2.5.3	DIST. SYSTEM, DEVICES	0.082	9.091	9.173
1.1.2.6	MAINTENANCE	833.812	78.967	912.779
1.1.2.6.1	MAINTENANCE - FREE FLYERS	0.0	42.551	42.551
1.1.2.6.2	GANTRY CRANE	106.540	0.257	106.797
1.1.2.6.3	ON-CRANE CONTROL CENTER	727.272	35.456	762.728
1.1.2.6.4	TRACKS & ACCESS WAYS	0.0	0.702	0.702
1.1.3	INFORMATION MGMT. & CONTROL - SATELLITE	97.615	229.787	327.402
1.1.3.1	MASTER CONTROL COMPUTER	18.869	9.179	28.048
1.1.3.2	DISPLAYS & CONTROLS	12.572	1.417	13.989
1.1.3.3	SUPERVISORY COMPUTER	3.221	2.721	5.941
1.1.3.4	REMOTE COMPUTER	3.093	6.664	9.757
1.1.3.5	BUS CONTROL UNIT	3.672	8.119	11.792
1.1.3.6	MICROPROCESSORS	3.750	7.910	11.659
1.1.3.7	REMOTE ACQUISITION & CONTROL	3.668	8.716	12.384
1.1.3.8	SUBMULTIPLEXORS	2.356	77.359	79.715
1.1.3.9	INSTRUMENTATION	33.813	89.513	123.326
1.1.3.10	OPTICAL FIBER	0.945	0.742	1.687
1.1.3.11	CABLES/HARNESS	11.657	17.447	29.104
1.1.4	ATTITUDE CONTROL & STATIONKEEPING -SATELLITE	15.192	81.259	96.451
1.1.4.1	ACS HARDWARE	15.192	81.259	96.451
1.1.4.1.1	ACS THRUSTER COMPONENTS	6.635	79.004	85.638
1.1.4.1.2	ACS - CONDUCTORS & INSULATION	0.892	0.009	0.901
1.1.4.1.3	ACS - POWER PROCESSING EQUIPMENT	1.438	0.936	2.374
1.1.4.1.4	ACS - THRUSTER GIMBALS AND MOUNTING	6.227	1.310	7.538

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE B-8. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DDT&E	DEVELOPMENT TFU	TOTAL
1.1.4.2	ACSS PROPELLANT	0.0	0.0	0.0
1.1.5	COMMUNICATIONS - SATELLITE	0.0	0.0	0.0
1.1.5.1	SATELLITE TO GROUND	0.0	0.0	0.0
1.1.5.2	SATELLITE TO RESUPPLY VEHICLES	0.0	0.0	0.0
1.1.5.3	SATELLITE INTERCOM	0.0	0.0	0.0
1.1.6	INTERFACE - SATELLITE	29.711	74.002	103.713
1.1.6.1	STRUCTURE	16.792	17.709	34.501
1.1.6.1.1	PRIMARY STRUCTURE	8.645	7.956	16.601
1.1.6.1.2	SECONDARY STRUCTURE	8.147	9.753	17.900
1.1.6.2	MECHANISMS - INTERFACE	8.043	19.337	27.380
1.1.6.3	POWER DISTRIBUTION	4.876	4.276	9.152
1.1.6.3.1	CONDUCTOR & INSULATION	3.832	1.268	5.100
1.1.6.3.2	SLIP RING BRUSHES	1.044	3.008	4.052
1.1.6.4	THERMAL CONTROL	0.0	0.0	0.0
1.1.6.5	MAINTENANCE	0.0	32.680	32.680
1.1.6.5.1	MAINTENANCE - FREE FLYERS	0.0	8.810	8.810
1.1.6.5.2	MANNED MANIPULATOR	0.0	22.467	22.467
1.1.6.5.3	TRACKS & ACCESS WAYS	0.0	1.404	1.404
1.1.7	SYSTEMS TEST - SATELLITE	4978.184	0.0	4978.184
1.1.7.1	SYSTEM GROUND TEST HARDWARE	2489.092	0.0	2489.092
1.1.7.2	SYSTEM GROUND TEST OPERATIONS	2489.092	0.0	2489.092
1.1.8	GROUND SUPPORT EQUIPMENT- SATELLITE	629.907	0.0	629.907
1.1.9	PROOF-OF-CONCEPT PILOT PLANT	870.085	4303.941	5174.023
1.1.9.1	COTV PRECURSOR VEHICLE	870.085	1077.751	1947.836
1.1.9.1.1	PRIMARY STRUCTURE - E.C.	75.738	2.398	78.137
1.1.9.1.2	SECONDARY STRUCTURE - E.C.	27.346	60.315	87.662
1.1.9.1.3	MECHANISMS - PRECURSOR E.C.	21.261	10.600	31.860
1.1.9.1.4	CONCENTRATOR - E.C.	9.254	3.329	12.583
1.1.9.1.5	SOLAR BLANKET -E.C.	67.440	89.271	156.711
1.1.9.1.6	SWITCHGEAR & REGULATORS - E.C.	5.205	6.809	12.014
1.1.9.1.7	LO-VOLTAGE CONVERTERS - E.C	1.854	0.211	2.064
1.1.9.1.8	CONDUCTORS & INSULATION - E.C.	7.492	1.212	8.704
1.1.9.1.9	ACS HARDWARE - E.C.	11.893	344.323	356.216
1.1.9.1.10	ACS - CONDUCTORS & INSUL - E.C.	2.439	0.030	2.469
1.1.9.1.11	ACS - BATTERIES - E.C.	7.839	49.789	57.627

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE B-8. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DDT&E	DEVELOPMENT TFU	TOTAL
1.1.9.1.12	ACS - BATTERY PD&C - E.C.	14.514	11.954	26.469
1.1.9.1.13	SLIPRINGS - PRECURSOR E.C.	26.862	1.926	28.788
1.1.9.1.14	TRACKS & ACCESS WAYS - E.C.	0.0	2.047	2.047
1.1.9.1.15	PRIMARY STRUCTURE - INTERFACE	197.661	7.956	205.617
1.1.9.1.16	SECONDARY STRUCTURE - INTERFACE	8.734	6.462	15.196
1.1.9.1.17	MECHANISMS - INTERFACE	17.193	31.176	48.369
1.1.9.1.18	CONDUCTORS & INSULATION - INTERFACE	2.807	0.044	2.851
1.1.9.1.19	SLIPRING BRUSHES - PRECURSOR - INTERFACE	1.171	0.117	1.288
1.1.9.1.20	PRIMARY STRUCTURE - POWER TRANS	22.915	1.345	24.260
1.1.9.1.21	SECONDARY STRUCTURE - POWER TRANS	19.845	32.204	52.049
1.1.9.1.22	MECHANISMS - POWER TRANS.	13.312	1.899	15.210
1.1.9.1.23	P.T. KLYSTRON SUBARRAY DDT&E	91.513	0.0	91.513
1.1.9.1.24	P.T. KLYSTRON WAVEGUIDE	0.0	2.192	2.192
1.1.9.1.25	P.T. KLYSTRON HEATPIPES	0.0	18.938	18.938
1.1.9.1.26	P.T. KLYSTRON P.M. ELEMENT	0.0	14.742	14.742
1.1.9.1.27	P.T. KLYSTRON PHASE SHIFTERS	0.0	7.371	7.371
1.1.9.1.28	P. T. KLYSTRON PH. CONTROL ELECTRONICS	0.0	6.016	6.016
1.1.9.1.29	P. T. KLYSTRON POWER DIVIDERS AND COMBINERS	0.0	0.958	0.958
1.1.9.1.30	KLYSTRON SUBARRAY SYSTEM INTEGRATION	0.0	20.926	20.926
1.1.9.1.31	PD&C - SW. GR. & REGULATORS - P.T.	6.159	8.003	14.162
1.1.9.1.32	PD&C - HI VOLTAGE CONVERT - P.T.	8.183	16.287	24.470
1.1.9.1.33	PD&C - LO VOLTAGE CONVERT - P.T.	1.338	0.070	1.408
1.1.9.1.34	PD&C CONDUCTORS & INSULATION - P. T.	3.777	0.121	3.897
1.1.9.1.35	BATTERIES - P.T. PRECURSOR	31.793	14.974	46.767
1.1.9.1.36	P.T. - BATTERY PD&C	5.265	9.564	14.828
1.1.9.1.37	THERMAL CONTROL - INSULATION - PRECURSOR R.T.	33.170	58.742	91.912
1.1.9.1.38	REFERENCE FREQUENCY GENERATOR - PRECURSOR	0.585	0.117	0.702
1.1.9.1.39	DIST. SYSTEM, COAXIAL CABLE	0.302	0.605	0.907
1.1.9.1.40	DIST. SYSTEM DEVICES	0.026	0.585	0.611
1.1.9.1.41	P.T. - MASTER CONTROL COMPUTER - IMS/COM	27.076	11.186	38.263
1.1.9.1.42	P.T. BUS CONTROL UNIT	10.898	6.727	17.625
1.1.9.1.43	P.T. - MICROPROCESSORS - IMS/COM	9.763	5.936	15.699
1.1.9.1.44	P.T. - REMOTE ACQ & CONTROL - IMS/COM	1.588	7.519	9.107
1.1.9.1.45	P.T. - SUBMULTIPLEXER - IMS/COM	4.744	163.751	168.495
1.1.9.1.46	P.T. - INSTRUMENTATION - IMS/COM	1.170	4.680	5.850

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE B-8. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DEVELOPMENT DDT&E	DEVELOPMENT TFU	TOTAL
1.1.9.1.47	P.T. - CABLES & HARNESS - IMS/COM	4.350	0.744	5.094
1.1.9.1.48	P.T. TRACKS AND ACCESSWAYS FOR MW ANT	28.342	0.702	29.044
1.1.9.1.49	P.T. ANT. MW LIFTS - INSTALL & C/O EQUIP.	37.272	30.881	68.153
1.1.9.2	PRECURSOR OPERATIONS	0.0	3221.191	3221.191
1.1.9.2.1	PRECURSOR STS TRANSPORTATION	0.0	3213.010	3213.010
1.1.9.2.2	PRECURSOR CONSTRUCTION CREW	0.0	6.571	6.571
1.1.9.2.3	PRECURSOR GEO TEST ACTIVITY	0.0	0.600	0.600
1.1.9.2.4	PRECURSOR PROPELLANT	0.0	1.011	1.011
1.1.9.3	PRECURSOR GROUND RECEIVING FACILITY	0.0	5.000	5.000
1.2	SPACE CONSTRUCTION & SUPPORT	8564.035	10757.824	19321.859
1.2.1	CONSTRUCTION FACILITIES	4260.855	7827.523	12088.379
1.2.1.1	WORK SUPPORT FACILITIES	3604.684	4662.012	8266.695
1.2.1.1.1	BEAM MACHINE	2.340	118.220	120.560
1.2.1.1.2	BEAM MACHINE CASSETTES SET	0.936	7.389	8.325
1.2.1.1.3	CABLE ATTACHMENT MACHINE	5.031	35.576	40.607
1.2.1.1.4	REMOTE MANIPULATOR	4.025	65.929	69.954
1.2.1.1.5	BLANKET DISPENSER MACHINE	4.680	33.076	37.756
1.2.1.1.6	SOLAR BLANKET CASSETTES	1.170	22.815	23.985
1.2.1.1.7	REFLECTOR DISPENSER MACHINE	7.020	5.442	12.462
1.2.1.1.8	REFLECTOR CASSETTES	1.170	3.184	4.354
1.2.1.1.9	CABLE/CATENARY DISPENSER MACHINES	2.574	26.660	29.234
1.2.1.1.10	ANTENNA PANEL INS. EQPT.	93.600	234.318	327.918
1.2.1.1.11	GANTRY/CRANES	15.912	99.490	115.402
1.2.1.1.12	CARGO STORAGE DEPOTS	4.387	8.844	13.231
1.2.1.1.13	FAB FIXTURE	2533.200	96.461	2629.660
1.2.1.1.14	AIRLOCK DOCKING MODULE (ADM)	0.0	283.493	283.493
1.2.1.1.15	BASE MGMT. MODULE (BMM)	0.0	1420.228	1420.228
1.2.1.1.16	POWER MODULE (PM)	0.0	1258.288	1258.288
1.2.1.1.17	PRESSURIZED STORAGE MODULE (PSM)	928.641	942.619	1871.260
1.2.1.2	CREW SUPPORT FACILITIES-SCB	656.174	3030.639	3686.813
1.2.1.2.1	AIRLOCK DOCKING MODULE-ADM	36.448	85.893	122.341
1.2.1.2.2	CREW HABITABILITY MODULE-CHM	0.0	1912.313	1912.313
1.2.1.2.3	CONSUMABLES LOGISTICS MODULE-CLM	0.0	707.469	707.469
1.2.1.2.4	SHIELDING	401.544	24.757	426.301
1.2.1.2.5	CREW SUPPORT MODULE-CSM	218.182	300.206	518.388

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE B-8. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

		DEVELOPMENT		
WBS #	DESCRIPTION	DDT&E	TFU	TOTAL
1.2.1.3	OPERATIONS	0.0	134.873	134.873
1.2.1.3.1	OPERATIONS, CONSTRUCTION CREW	0.0	92.574	92.574
1.2.1.3.2	ORBITAL OPERATIONS,CONST. PROV.	0.0	42.299	42.299
1.2.2	LOGISTICS SUPPORT FACILITIES-LEO	4303.180	1091.385	5394.562
1.2.2.1	WORK SUPPORT FACILITIES	3293.540	703.519	3997.058
1.2.2.1.1	BASE MGMT. MODULE-BMM	2884.040	363.652	3247.693
1.2.2.1.2	POWER MODULE-PM	409.500	322.187	731.687
1.2.2.1.3	AIRLOCK DOCKING MODULE - ADM	0.0	17.679	17.679
1.2.2.2	CREW SUPPORT FACILITIES	1009.642	384.675	1394.317
1.2.2.2.1	CREW HABITABILITY MODULE-CHM	306.865	119.256	426.121
1.2.2.2.2	CONSUMABLES LOGISTICS MODULE CLM	310.050	82.011	392.061
1.2.2.2.3	CREW SUPPORT MODULE/EVA	392.727	183.408	576.135
1.2.2.3	OPERATIONS	0.0	3.191	3.191
1.2.2.3.1	LEO OPERATIONS CREW	0.0	2.190	2.190
1.2.2.3.2	LEO CREW PROVISIONS	0.0	1.001	1.001
1.2.3	O&M SUPPORT FACILITIES - SATELLITE	0.0	1838.918	1838.918
1.2.3.1	WORK SUPPORT FACILITIES	0.0	1633.609	1633.609
1.2.3.1.1	AIRLOCK DOCKING MODULE-ADM	0.0	34.987	34.987
1.2.3.1.2	BASE MGMT MODULE-BMM	0.0	719.661	719.661
1.2.3.1.3	PRESSURIZED STORAGE MODULE-PSM	0.0	241.360	241.360
1.2.3.1.4	POWER MODULE-PM	0.0	637.602	637.602
1.2.3.2	CREW SUPPORT FACILITIES	0.0	201.268	201.268
1.2.3.2.1	CREW HABITABILITY MODULE-CHM	0.0	119.256	119.256
1.2.3.2.2	CONSUMABLES LOGISTICS MODULE-CLM	0.0	82.011	82.011
1.2.3.3	OPERATIONS	0.0	4.042	4.042
1.2.3.3.1	SATELLITE OPERATIONS CREW - SCB	0.0	0.584	0.584
1.2.3.3.2	SATELLITE OPERATIONS CREW - MMB	0.0	2.190	2.190
1.2.3.3.3	CREW PROVISIONS - SCB	0.0	0.267	0.267
1.2.3.3.4	O&M CREW PROVISIONS - MMB	0.0	1.001	1.001
1.3	TRANSPORTATION	13154.137	23334.477	36488.613
1.3.1	SPS-HEAVY LIFT LAUNCH VEHICLE(HLLV)	10062.000	11632.133	21694.133
1.3.1.1	SPS-HLLV FLEET	10062.000	10921.242	20983.242
1.3.1.2	SPS-HLLV OPERATIONS (VTO-HL)	0.0	710.892	710.892
1.3.2	CARGO ORBITAL TRANSFER VEHICLE(COTV)	128.530	4578.930	4707.457
1.3.2.1	COTV VEHICLES	128.530	4571.391	4699.918

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE B-8. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DEVELOPMENT DDT&E	DEVELOPMENT TFU	TOTAL
1.3.2.1.1	PRIMARY STRUCTURE	12.004	14.391	26.395
1.3.2.1.2	SECONDARY STRUCTURE	12.015	320.645	332.659
1.3.2.1.3	MECHANISMS - EOTV	8.409	25.440	33.849
1.3.2.1.4	TRACKS AND ACCESSWAYS	0.0	1.053	1.053
1.3.2.1.5	CONCENTRATOR	1.981	18.716	20.697
1.3.2.1.6	SOLAR BLANKET	39.058	499.988	539.046
1.3.2.1.7	SWITCHGEAR AND REGULATORS	2.781	13.407	16.188
1.3.2.1.8	LO-VOLTAGE CONVERTERS	1.207	1.011	2.218
1.3.2.1.9	CONDUCTORS AND INSULATION	3.807	7.441	11.248
1.3.2.1.10	BATTERIES	4.310	1707.046	1711.356
1.3.2.1.11	BATTERY PD&C	6.421	71.727	78.148
1.3.2.1.12	ACS HARDWARE-COTV	9.461	1756.297	1765.758
1.3.2.1.13	INFO. MGMT. AND CONTROL	27.076	134.238	161.314
1.3.2.2	COTV OPERATIONS	0.0	7.541	7.541
1.3.3	STS PERSONNEL CARGO LAUNCH VEHICLE	286.650	3022.765	3309.415
1.3.3.1	STS CARGO CARRIER AND EM	286.650	607.795	894.445
1.3.3.2	STS OPERATIONS - GROWTH AND DERIVATIVE HLLV	0.0	2414.970	2414.970
1.3.3.2.1	OPERATIONS-STS GROWTH HLLV	0.0	1458.000	1458.000
1.3.3.2.2	OPERATIONS - STS DERIVATIVE	0.0	956.970	956.970
1.3.4	PERSONNEL ORBITAL TRANS VEHICLE	409.500	67.937	477.437
1.3.4.1	POTV-FLEET	409.500	66.328	475.828
1.3.4.2	POTV-OPERATIONS	0.0	1.609	1.609
1.3.5	PERSONNEL MODULE(PM)	138.060	287.814	425.874
1.3.5.1	PM FLEET	138.060	284.830	422.890
1.3.5.2	PM OPERATIONS	0.0	2.983	2.983
1.3.6	INTRAORBITAL TRANSFER VEHICLE(IOTV)	117.000	6.753	123.753
1.3.6.1	IOTV FLEET	117.000	6.633	123.633
1.3.6.2	IOTV OPERATIONS	0.0	0.120	0.120
1.3.7	GROUND SUPPORT FACILITIES	2012.400	3738.150	5750.547
1.3.7.1	LAUNCH FACILITIES	0.0	0.0	0.0
1.3.7.2	RECOVERY FACILITIES	0.0	0.0	0.0
1.3.7.3	FUEL FACILITIES	0.0	0.0	0.0
1.3.7.4	LOGISTICS SUPPORT	0.0	0.0	0.0
1.3.7.5	OPERATIONS	0.0	0.0	0.0
1.4	GROUND RECEIVING STATION	135.368	4249.754	4385.121

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION, 1980

TABLE B-8. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DDT&E	DEVELOPMENT TFU	TOTAL
1.4.1	SITE AND FACILITIES	1.170	228.381	229.551
1.4.1.1	LAND AND PREPARATION	0.0	123.248	123.248
1.4.1.1.1	LAND	0.0	40.950	40.950
1.4.1.1.2	LAND PREPARATION	0.0	82.298	82.298
1.4.1.2	ROADS AND FENCES	0.0	86.791	86.791
1.4.1.2.1	RAILS AND ROADS	0.0	86.241	86.241
1.4.1.2.2	FENCING	0.0	0.550	0.550
1.4.1.3	UTILITIES	0.0	0.234	0.234
1.4.1.4	BUILDINGS	0.0	13.428	13.428
1.4.1.4.1	STORAGE,MAINTENANCE FACILITIES	0.0	1.521	1.521
1.4.1.4.2	CONV. STA. & MONITOR/CONTROL FAC.	0.0	11.907	11.907
1.4.1.5	MAINTENANCE EQPT. FOR SITE & FACILITIES	0.0	4.680	4.680
1.4.1.6	LIGHTNING PROTECTION	0.0	0.0	0.0
1.4.1.7	SITE & FACILITIES DDT&E	1.170	0.0	1.170
1.4.2	RECTENNA SUPPORT STRUCTURE	2.340	2164.186	2166.526
1.4.2.1	STEEL PANEL FAB. & INSTALLATION	0.0	1985.034	1985.034
1.4.2.1.1	HAT SECTIONS	0.0	420.416	420.416
1.4.2.1.2	WIDE FLANGES	0.0	345.352	345.352
1.4.2.1.3	TUBE BRACES & HARDWARE	0.0	504.675	504.675
1.4.2.1.4	ASSEMBLY & INSTALLATION	0.0	714.591	714.591
1.4.2.2	TRENCHING & CONCRETE INSTALLATION	0.0	179.152	179.152
1.4.2.2.1	FOOTING CONCRETE & RE-BAR	0.0	82.861	82.861
1.4.2.2.2	MACHINGERY & EQUIPMENT - GRS CONSTRUCTION	0.0	26.161	26.161
1.4.2.2.3	CONSTRUCTION OPERATIONS	0.0	70.130	70.130
1.4.2.3	SUPPORT STRUCTURE DDT&E	2.340	0.0	2.340
1.4.3	POWER COLLECTION	3.510	1583.257	1586.767
1.4.3.1	ANTENNA ARRAY ELEMENTS	0.0	1318.978	1316.978
1.4.3.2	POWER DISTRIBUTION SYSTEM	0.0	81.502	81.502
1.4.3.3	INSTALLATION & CHECKOUT	0.0	182.777	182.777
1.4.3.4	POWER COLLECTION-DDT&E	3.510	0.0	3.510
1.4.4	CONTROL	11.700	87.750	99.450
1.4.4.1	CONTROL CENTER EQUIPMENT	0.0	17.550	17.550
1.4.4.2	CONTROL ELECTRONICS	0.0	70.200	70.200
1.4.4.3	CONTROL DDT&E	11.700	0.0	11.700
1.4.5	GRID INTERFACE	116.648	186.181	302.829

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION, 1980

TABLE B-8. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DEVELOPMENT DDT&E	DEVELOPMENT TFU	TOTAL
1.4.5.1	ELECTRICAL EQUIPMENT	0.0	186.181	186.181
1.4.5.2	GRID INTERFACE-DDT&E	116.648	0.0	116.648
1.4.6	OPERATIONS	0.0	0.0	0.0
1.4.6.1	OPER. & MAINT. PERSONNEL	0.0	0.0	0.0
1.4.6.2	MAINT. MATERIAL	0.0	0.0	0.0
1.5	MANAGEMENT AND INTEGRATION	1482.630	2407.669	3890.299
1.6	MASS CONTINGENCY	2454.463	3085.372	5539.832

B.4.2 INVESTMENT AND OPERATIONS

Summarized line item costing information on the investments per SPS, including replacement capital (RCI) and operations/maintenance during construction periods preceding SPS-IOC is presented in this section. These investment costs were developed at two levels:

1. Average investment per SPS is the cost of production, assembly, installation, transportation, and testing/validation of SPS program elements including the satellite, space construction and support, transportation, and ground receiving station with an operational capability to produce electrical energy at the utility interface.

2. Replacement capital investment (RCI) and operations/maintenance (O&M) cost estimates are established on an annual basis. RCI/O&M represent capital asset replacements and major maintenance overhauls/spares that are expected to last for more than one year or result in an improvement to the operating system.

Investment per satellite is equivalent to the average cost of a total SPS requirement or option which covers all satellites and related program elements needed to establish operational systems. Although details are not included in this appendix, cost estimates were developed for five SPS concepts. Investment costs for these SPS programs are summarized in Table B-9 with reference to the SPS option quantity and power availability at the electric utility interface. RCI/O&M costs during the construction or pre-IOC period are included for various system elements.

A listing of line item costs are presented in Table B-10 itemizing estimates of the Rockwell SPS CR-2 reference (3-trough/planar/klystron) configuration (1980). This table identifies average investment cost estimates and pre-IOC replacement capital /O&M costs. RCI/O&M cost estimates are annular in this listing and should be multiplied by 30 in order to arrive at total costs associated with each SPS-WBS element. RCI/O&M estimates are listed in annular amounts to accommodate the calculation routine of the computer program and SPS option quantity requirements.

Table B-9. SPS Investment Costs ($\$\times10^6$)

SPS CONCEPT	TOTAL: SPS PROGRAM INVEST-MENT	TOTAL: SPS RCI/O&M (PRE-IOC)	SATELLITE (1.1): PROGRAM INVEST-MENT	SATELLITE (1.1): RCI/O&M (PRE-IOC)	SPACE CONSTR. & SUPPORT (1.2): PROGRAM INVEST-MENT	SPACE CONSTR. & SUPPORT (1.2): RCI/O&M (PRE-IOC)	TRANSPORTA-TION (1.3): PRO-GRAM INV.	TRANSPORTA-TION (1.3): RCI/O&M (PRE-IOC)	GRD. RECV. STA. (1.4): PRO-GRAM INV.	GRD. RECV. STA. (1.4): RCI/O&M (PRE-IOC)	MGMT. & INTEG. (1.5): PRO-GRAM INV.	MGMT. & INTEG. (1.5): RCI/O&M (PRE-IOC)	MASS CON-TING. (1.6): PRO-GRAM INV.	MASS CON-TING. (1.6): RCI/O&M (PRE-IOC)	SPS OPTION: QTY	GW_{UTIL}
CR-2 REFERENCE CONFIG. (3-TROUGH/PLANAR/ KLYSTRON GaAs	12,743	2,341	4,978	-	210	241	1990	1904	4217	50	570	110	778	36	60	5.00
TOTAL	15,084		4,978		451		3894		4267		680		814			
CR-2 MAGNETRON CONFIG. (3-TROUGH/PLANAR) GaAs	11,823	2,231	3,752	-	225	314	1777	1707	4938	59	534	104	597	47	54	5.60
TOTAL	14,054		3,752		539		3484		4997		638		644			
CR-2 SOLID-STATE GaAs (3-TROUGH/PLANAR/ DUAL END-MOUNTED ANT.	14,977	2,795	6,062	-	215	250	2447	2321	4643	55	668	131	942	38	58	5.22
TOTAL	17,772		6,062		465		4768		4698		799		980			
SOLID-STATE GaAs SANDWICH CR-5 CONFIG. (DUAL REFLECTOR ANTENNAS)	7,396	1,461	3,203	-	107	183	1265	1172	1996	11	329	68	496	27	125	2.42
TOTAL	8,857		3,203		290		2437		2007		397		523			
SOLID-STATE GaAlAs MBG SANDWICH CR-5 (DUAL REFLECTORS/ ANTENNAS	7,834	1,331	3,255	-	137	214	1087	1009	2497	14	349	62	509	32	95	3.06
TOTAL	9,165		3,255		351		2096		2511		411		541			

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION, 1980

TABLE B-10. SATELLITE POWER SYSTEM (SPS) PROGRAM PRE-IOC COSTS

WBS #	DESCRIPTION	INV PER SAT	****PRE-IOC ********* AVERAGE OPS COST PER SAT/YR RCI-PRE	O&M-PRE	TOTAL PRE-IOC
1	SATELLITE POWER SYSTEM (SPS) PROGRAM	12742.617	71.944	6.104	78.048
1.1	SATELLITE SYSTEM	4978.184	0.0	0.0	0.0
1.1.1	ENERGY CONVERSION - SATELLITE	2349.125	0.0	0.0	0.0
1.1.1.1	STRUCTURE	195.373	0.0	0.0	0.0
1.1.1.1.1	PRIMARY STRUCTURE	54.288	0.0	0.0	0.0
1.1.1.1.2	SECONDARY STRUCTURE	137.181	0.0	0.0	0.0
1.1.1.1.3	MECHANISMS	3.904	0.0	0.0	0.0
1.1.1.2	CONCENTRATORS	82.586	0.0	0.0	0.0
1.1.1.3	SOLAR BLANKETS	1916.473	0.0	0.0	0.0
1.1.1.4	POWER DIST. & CONDITIONING	105.185	0.0	0.0	0.0
1.1.1.4.1	SWITCH GEAR & REGULATORS - E.C.	75.085	0.0	0.0	0.0
1.1.1.4.2	LO-VOLTAGE CONVERTERS - E.C.	3.655	0.0	0.0	0.0
1.1.1.4.3	CONDUCTORS & INSULATION	11.209	0.0	0.0	0.0
1.1.1.4.4	SLIP RINGS	13.766	0.0	0.0	0.0
1.1.1.4.5	BATTERIES	0.223	0.0	0.0	0.0
1.1.1.4.6	BATTERY PD&C	1.247	0.0	0.0	0.0
1.1.1.5	THERMAL CONTROL	0.0	0.0	0.0	0.0
1.1.1.6	MAINTENANCE	49.509	0.0	0.0	0.0
1.1.1.6.1	MAINTENANCE - FREE FLYERS	27.006	0.0	0.0	0.0
1.1.1.6.2	MANNED MANIPULATOR	17.588	0.0	0.0	0.0
1.1.1.6.3	TRACKS & ACCESS WAYS	4.914	0.0	0.0	0.0
1.1.2	POWER TRANSMISSION - SATELLITE	2304.016	0.0	0.0	0.0
1.1.2.1	STRUCTURE	191.573	0.0	0.0	0.0
1.1.2.1.1	PRIMARY STRUCTURE	1.345	0.0	0.0	0.0
1.1.2.1.2	SECONDARY STRUCTURE	188.962	0.0	0.0	0.0
1.1.2.1.3	MECHANISMS (TRUNNIONS)	1.266	0.0	0.0	0.0
1.1.2.2	TRANSMITTER SUBARRAYS - KLYSTRONS	1459.600	0.0	0.0	0.0
1.1.2.2.1	KLYSTRON MPT & RS DDT&E	0.0	0.0	0.0	0.0
1.1.2.2.2	WAVE GUIDE	34.293	0.0	0.0	0.0
1.1.2.2.3	HEAT PIPES -THERMAL	296.216	0.0	0.0	0.0
1.1.2.2.4	KLYSTRON POWER MODULE ELEMENT	268.920	0.0	0.0	0.0
1.1.2.2.5	PHASE SHIFTERS	144.651	0.0	0.0	0.0
1.1.2.2.6	PHASE CONTROL ELECTRONICS	125.876	0.0	0.0	0.0
1.1.2.2.7	POWER DIVIDERS & COMBINERS	20.035	0.0	0.0	0.0
1.1.2.2.8	MW SYSTEM INTEGRATION	569.607	0.0	0.0	0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION, 1980

TABLE B-10. SATELLITE POWER SYSTEM (SPS) PROGRAM PRE-IOC COSTS

WBS #	DESCRIPTION	INV AVERAGE PER SAT	****PRE-IOC ********* OPS COST PER SAT/YR RCI-PRE	O&M-PRE	TOTAL PRE-IOC
1.1.2.3	POWER DIST. & CONDITIONING	385.275	0.0	0.0	0.0
1.1.2.3.1	SWITCH GEAR & REGULATORS	75.807	0.0	0.0	0.0
1.1.2.3.2	HI-VOLTAGE CONVERTERS	269.643	0.0	0.0	0.0
1.1.2.3.3	LO-VOLTAGE CONVERTERS	1.164	0.0	0.0	0.0
1.1.2.3.4	CONDUCTORS & INSULATION	3.618	0.0	0.0	0.0
1.1.2.3.5	BATTERIES	10.457	0.0	0.0	0.0
1.1.2.3.6	BATTERY P&C	24.587	0.0	0.0	0.0
1.1.2.4	THERMAL CONTROL - INSULATION	150.982	0.0	0.0	0.0
1.1.2.5	CONTROL - PHASE REFERENCE	51.328	0.0	0.0	0.0
1.1.2.5.1	REFERENCE FREQUENCY GENERATOR	0.117	0.0	0.0	0.0
1.1.2.5.2	DIST. SYSTEM, COAXIAL CABLE	42.120	0.0	0.0	0.0
1.1.2.5.3	DIST. SYSTEM, DEVICES	9.091	0.0	0.0	0.0
1.1.2.6	MAINTENANCE	65.259	0.0	0.0	0.0
1.1.2.6.1	MAINTENANCE - FREE FLYERS	33.245	0.0	0.0	0.0
1.1.2.6.2	GANTRY CRANE	0.257	0.0	0.0	0.0
1.1.2.6.3	ON-CRANE CONTROL CENTER	31.055	0.0	0.0	0.0
1.1.2.6.4	TRACKS & ACCESS WAYS	0.702	0.0	0.0	0.0
1.1.3	INFORMATION MGMT. & CONTROL - SATELL	189.170	0.0	0.0	0.0
1.1.3.1	MASTER CONTROL COMPUTER	3.021	0.0	0.0	0.0
1.1.3.2	DISPLAYS & CONTROLS	0.515	0.0	0.0	0.0
1.1.3.3	SUPERVISORY COMPUTER	1.109	0.0	0.0	0.0
1.1.3.4	REMOTE COMPUTER	2.560	0.0	0.0	0.0
1.1.3.5	BUS CONTROL UNIT	5.958	0.0	0.0	0.0
1.1.3.6	MICROPROCESSORS	5.604	0.0	0.0	0.0
1.1.3.7	REMOTE ACQUISITION & CONTROL	6.395	0.0	0.0	0.0
1.1.3.8	SUBMULTIPLEXORS	68.467	0.0	0.0	0.0
1.1.3.9	INSTRUMENTATION	79.222	0.0	0.0	0.0
1.1.3.10	OPTICAL FIBER	0.675	0.0	0.0	0.0
1.1.3.11	CABLES/HARNESS	15.444	0.0	0.0	0.0
1.1.4	ATTITUDE CONTROL & STATIONKEEPING -S	72.235	0.0	0.0	0.0
1.1.4.1	ACS HARDWARE	72.235	0.0	0.0	0.0
1.1.4.1.1	ACS THRUSTER COMPONENTS	69.979	0.0	0.0	0.0
1.1.4.1.2	ACS - CONDUCTORS & INSULATION	0.009	0.0	0.0	0.0
1.1.4.1.3	ACS - POWER PROCESSING EQUIPMENT	0.936	0.0	0.0	0.0
1.1.4.1.4	ACS - THRUSTER GIMBALS AND MOUNTING	1.310	0.0	0.0	0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION, 1980

TABLE B-10. SATELLITE POWER SYSTEM (SPS) PROGRAM PRE-IOC COSTS

WBS #	DESCRIPTION	INV PER SAT	****PRE-IOC ********* AVERAGE OPS COST PER SAT/YR RCI-PRE	O&M-PRE	TOTAL PRE-IOC
1.1.4.2	ACSS PROPELLANT	0.0	0.0	0.0	0.0
1.1.5	COMMUNICATIONS - SATELLITE	0.0	0.0	0.0	0.0
1.1.5.1	SATELLITE TO GROUND	0.0	0.0	0.0	0.0
1.1.5.2	SATELLITE TO RESUPPLY VEHICLES	0.0	0.0	0.0	0.0
1.1.5.3	SATELLITE INTERCOM	0.0	0.0	0.0	0.0
1.1.6	INTERFACE - SATELLITE	63.641	0.0	0.0	0.0
1.1.6.1	STRUCTURE	16.604	0.0	0.0	0.0
1.1.6.1.1	PRIMARY STRUCTURE	7.956	0.0	0.0	0.0
1.1.6.1.2	SECONDARY STRUCTURE	8.648	0.0	0.0	0.0
1.1.6.2	MECHANISMS - INTERFACE	17.173	0.0	0.0	0.0
1.1.6.3	POWER DISTRIBUTION	3.470	0.0	0.0	0.0
1.1.6.3.1	CONDUCTOR & INSULATION	1.268	0.0	0.0	0.0
1.1.6.3.2	SLIP RING BRUSHES	2.201	0.0	0.0	0.0
1.1.6.4	THERMAL CONTROL	0.0	0.0	0.0	0.0
1.1.6.5	MAINTENANCE	26.394	0.0	0.0	0.0
1.1.6.5.1	MAINTENANCE - FREE FLYERS	7.437	0.0	0.0	0.0
1.1.6.5.2	MANNED MANIPULATOR	17.553	0.0	0.0	0.0
1.1.6.5.3	TRACKS & ACCESS WAYS	1.404	0.0	0.0	0.0
1.1.7	SYSTEMS TEST - SATELLITE	0.0	0.0	0.0	0.0
1.1.7.1	SYSTEM GROUND TEST HARDWARE	0.0	0.0	0.0	0.0
1.1.7.2	SYSTEM GROUND TEST OPERATIONS	0.0	0.0	0.0	0.0
1.1.8	GROUND SUPPORT EQUIPMENT- SATELLITE	0.0	0.0	0.0	0.0
1.1.9	PROOF-OF-CONCEPT PILOT PLANT	0.0	0.0	0.0	0.0
1.1.9.1	COTV PRECURSOR VEHICLE	0.0	0.0	0.0	0.0
1.1.9.1.1	PRIMARY STRUCTURE - E.C.	0.0	0.0	0.0	0.0
1.1.9.1.2	SECONDARY STRUCTURE - E.C.	0.0	0.0	0.0	0.0
1.1.9.1.3	MECHANISMS - PRECURSOR E.C.	0.0	0.0	0.0	0.0
1.1.9.1.4	CONCENTRATOR - E.C.	0.0	0.0	0.0	0.0
1.1.9.1.5	SOLAR BLANKET -E.C.	0.0	0.0	0.0	0.0
1.1.9.1.6	SWITCHGEAR & REGULATORS - E.C.	0.0	0.0	0.0	0.0
1.1.9.1.7	LO-VOLTAGE CONVERTERS - E.C	0.0	0.0	0.0	0.0
1.1.9.1.8	CONDUCTORS & INSULATION - E.C.	0.0	0.0	0.0	0.0
1.1.9.1.9	ACS HARDWARE - E.C.	0.0	0.0	0.0	0.0
1.1.9.1.10	ACS - CONDUCTORS & INSUL - E.C.	0.0	0.0	0.0	0.0
1.1.9.1.11	ACS - BATTERIES - E.C.	0.0	0.0	0.0	0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE B-10. SATELLITE POWER SYSTEM (SPS) PROGRAM PRE-IOC COSTS

WBS #	DESCRIPTION	****PRE-IOC ********* AVERAGE OPS COST PER SAT/YR INV PER SAT	RC1-PRE	O&M-PRE	TOTAL PRE-IOC
1.1.9.1.12	ACS - BATTERY PD&C - E.C.	0.0	0.0	0.0	0.0
1.1.9.1.13	SLIPRINGS - PRECURSOR E.C.	0.0	0.0	0.0	0.0
1.1.9.1.14	TRACKS & ACCESS WAYS - E.C.	0.0	0.0	0.0	0.0
1.1.9.1.15	PRIMARY STRUCTURE - INTERFACE	0.0	0.0	0.0	0.0
1.1.9.1.16	SECONDARY STRUCTURE - INTERFACE	0.0	0.0	0.0	0.0
1.1.9.1.17	MECHANISMS - INTERFACE	0.0	0.0	0.0	0.0
1.1.9.1.18	CONDUCTORS & INSULATION - INTERFACE	0.0	0.0	0.0	0.0
1.1.9.1.19	SLIPRING BRUSHES - PRECURSOR - INTER	0.0	0.0	0.0	0.0
1.1.9.1.20	PRIMARY STRUCTURE - POWER TRANS	0.0	0.0	0.0	0.0
1.1.9.1.21	SECONDARY STRUCTURE - POWER TRANS	0.0	0.0	0.0	0.0
1.1.9.1.22	MECHANISMS - POWER TRANS.	0.0	0.0	0.0	0.0
1.1.9.1.23	P.T. KLYSTRON SUBARRAY DDT&E	0.0	0.0	0.0	0.0
1.1.9.1.24	P.T. KLYSTRON WAVEGUIDE	0.0	0.0	0.0	0.0
1.1.9.1.25	P.T. KLYSTRON HEATPIPES	0.0	0.0	0.0	0.0
1.1.9.1.26	P.T. KLYSTRON P.M. ELEMENT	0.0	0.0	0.0	0.0
1.1.9.1.27	P.T. KLYSTRON PHASE SHIFTERS	0.0	0.0	0.0	0.0
1.1.9.1.28	P. T. KLYSTRON PH. CONTROL ELECTRONI	0.0	0.0	0.0	0.0
1.1.9.1.29	P. T. KLYSTRON POWER DIVIDERS AND CO	0.0	0.0	0.0	0.0
1.1.9.1.30	KLYSTRON SUBARRAY SYSTEM INTEGRATION	0.0	0.0	0.0	0.0
1.1.9.1.31	PD&C - SW. GR. & REGULATORS - P.T.	0.0	0.0	0.0	0.0
1.1.9.1.32	PD&C - HI VOLTAGE CONVERT - P.T.	0.0	0.0	0.0	0.0
1.1.9.1.33	PD&C - LO VOLTAGE CONVERT - P.T.	0.0	0.0	0.0	0.0
1.1.9.1.34	PD&C CONDUCTORS & INSULATION - P. T.	0.0	0.0	0.0	0.0
1.1.9.1.35	BATTERIES - P.T. PRECURSOR	0.0	0.0	0.0	0.0
1.1.9.1.36	P.T. - BATTERY PD&C	0.0	0.0	0.0	0.0
1.1.9.1.37	THERMAL CONTROL - INSULATION - PRECU	0.0	0.0	0.0	0.0
1.1.9.1.38	REFERENCE FREQUENCY GENERATOR - PREC	0.0	0.0	0.0	0.0
1.1.9.1.39	DIST. SYSTEM, COAXIAL CABLE	0.0	0.0	0.0	0.0
1.1.9.1.40	DIST. SYSTEM DEVICES	0.0	0.0	0.0	0.0
1.1.9.1.41	P.T. - MASTER CONTROL COMPUTER - IMS	0.0	0.0	0.0	0.0
1.1.9.1.42	P.T. BUS CONTROL UNIT	0.0	0.0	0.0	0.0
1.1.9.1.43	P.T. - MICROPROCESSORS - IMS/COM	0.0	0.0	0.0	0.0
1.1.9.1.44	P.T. - REMOTE ACQ & CONTROL - IMS/CO	0.0	0.0	0.0	0.0
1.1.9.1.45	P.T. - SUBMULTIPLEXER - IMS/COM	0.0	0.0	0.0	0.0
1.1.9.1.46	P.T. - INSTRUMENTATION - IMS/COM	0.0	0.0	0.0	0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE B-10. SATELLITE POWER SYSTEM (SPS) PROGRAM PRE-IOC COSTS

		****PRE-IOC *********			
		AVERAGE OPS COST PER SAT/YR			TOTAL
WBS #	DESCRIPTION	INV PER SAT	RCI-PRE	O&M-PRE	PRE-IOC
1.1.9.1.47	P.T. - CABLES & HARNESS - IMS/COM	0.0	0.0	0.0	0.0
1.1.9.1.48	P.T. TRACKS AND ACCESSWAYS FOR MW AN	0.0	0.0	0.0	0.0
1.1.9.1.49	P.T. ANT. MW LIFTS - INSTALL & C/O E	0.0	0.0	0.0	0.0
1.1.9.2	PRECURSOR OPERATIONS	0.0	0.0	0.0	0.0
1.1.9.2.1	PRECURSOR STS TRANSPORTATION	0.0	0.0	0.0	0.0
1.1.9.2.2	PRECURSOR CONSTRUCTION CREW	0.0	0.0	0.0	0.0
1.1.9.2.3	PRECURSOR GEO TEST ACTIVITY	0.0	0.0	0.0	0.0
1.1.9.2.4	PRECURSOR PROPELLANT	0.0	0.0	0.0	0.0
1.1.9.3	PRECURSOR GROUND RECEIVING FACILITY	0.0	0.0	0.0	0.0
1.2	SPACE CONSTRUCTION & SUPPORT	209.874	4.331	3.713	8.044
1.2.1	CONSTRUCTION FACILITIES	194.241	3.854	3.713	7.566
1.2.1.1	WORK SUPPORT FACILITIES	77.186	2.200	3.713	5.913
1.2.1.1.1	BEAM MACHINE	1.970	0.0	0.811	0.811
1.2.1.1.2	BEAM MACHINE CASSETTES SET	0.227	0.004	0.116	0.119
1.2.1.1.3	CABLE ATTACHMENT MACHINE	0.593	0.0	0.228	0.228
1.2.1.1.4	REMOTE MANIPULATOR	1.078	0.036	0.360	0.396
1.2.1.1.5	BLANKET DISPENSER MACHINE	0.551	0.0	0.183	0.183
1.2.1.1.6	SOLAR BLANKET CASSETTES	0.761	0.025	0.156	0.181
1.2.1.1.7	REFLECTOR DISPENSER MACHINE	0.091	0.0	0.028	0.028
1.2.1.1.8	REFLECTOR CASSETTES	0.098	0.002	0.042	0.044
1.2.1.1.9	CABLE/CATENARY DISPENSER MACHINES	0.444	0.0	0.074	0.074
1.2.1.1.10	ANTENNA PANEL INS. EQPT.	3.905	0.0	1.170	1.170
1.2.1.1.11	GANTRY/CRANES	1.658	0.0	0.281	0.281
1.2.1.1.12	CARGO STORAGE DEPOTS	0.147	0.0	0.023	0.023
1.2.1.1.13	FAB FIXTURE	1.608	0.0	0.241	0.241
1.2.1.1.14	AIRLOCK DOCKING MODULE (ADM)	4.638	0.155	0.0	0.155
1.2.1.1.15	BASE MGMT. MODULE (BMM)	23.303	0.776	0.0	0.776
1.2.1.1.16	POWER MODULE (PM)	20.646	0.688	0.0	0.688
1.2.1.1.17	PRESSURIZED STORAGE MODULE (PSM)	15.467	0.515	0.0	0.515
1.2.1.2	CREW SUPPORT FACILITIES-SCB	49.618	1.654	0.0	1.654
1.2.1.2.1	AIRLOCK DOCKING MODULE-ADM	1.408	0.047	0.0	0.047
1.2.1.2.2	CREW HABITABILITY MODULE-CHM	31.288	1.043	0.0	1.043
1.2.1.2.3	CONSUMABLES LOGISTICS MODULE-CLM	11.586	0.386	0.0	0.386
1.2.1.2.4	SHIELDING	0.406	0.014	0.0	0.014
1.2.1.2.5	CREW SUPPORT MODULE-CSM	4.930	0.164	0.0	0.164

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE B-10. SATELLITE POWER SYSTEM (SPS) PROGRAM PRE-IOC COSTS

WBS #	DESCRIPTION	INV PER SAT	****PRE-IOC ******** AVERAGE OPS COST PER SAT/YR RCI-PRE	O&M-PRE	TOTAL PRE-IOC
1.2.1.3	OPERATIONS	67.437	0.0	0.0	0.0
1.2.1.3.1	OPERATIONS, CONSTRUCTION CREW	46.287	0.0	0.0	0.0
1.2.1.3.2	ORBITAL OPERATIONS,CONST. PROV.	21.150	0.0	0.0	0.0
1.2.2	LOGISTICS SUPPORT FACILITIES-LEO	15.633	0.478	0.0	0.478
1.2.2.1	WORK SUPPORT FACILITIES	9.282	0.309	0.0	0.309
1.2.2.1.1	BASE MGMT. MODULE-BMM	4.798	0.160	0.0	0.160
1.2.2.1.2	POWER MODULE-PM	4.251	0.142	0.0	0.142
1.2.2.1.3	AIRLOCK DOCKING MODULE - ADM	0.233	0.008	0.0	0.008
1.2.2.2	CREW SUPPORT FACILITIES	5.075	0.169	0.0	0.169
1.2.2.2.1	CREW HABITABILITY MODULE-CHM	1.573	0.052	0.0	0.052
1.2.2.2.2	CONSUMABLES LOGISTICS MODULE CLM	1.082	0.036	0.0	0.036
1.2.2.2.3	CREW SUPPORT MODULE/EVA	2.420	0.081	0.0	0.081
1.2.2.3	OPERATIONS	1.276	0.0	0.0	0.0
1.2.2.3.1	LEO OPERATIONS CREW	0.876	0.0	0.0	0.0
1.2.2.3.2	LEO CREW PROVISIONS	0.400	0.0	0.0	0.0
1.2.3	O&M SUPPORT FACILITIES - SATELLITE	0.0	0.0	0.0	0.0
1.2.3.1	WORK SUPPORT FACILITIES	0.0	0.0	0.0	0.0
1.2.3.1.1	AIRLOCK DOCKING MODULE-ADM	0.0	0.0	0.0	0.0
1.2.3.1.2	BASE MGMT MODULE-BMM	0.0	0.0	0.0	0.0
1.2.3.1.3	PRESSURIZED STORAGE MODULE-PSM	0.0	0.0	0.0	0.0
1.2.3.1.4	POWER MODULE-PM	0.0	0.0	0.0	0.0
1.2.3.2	CREW SUPPORT FACILITIES	0.0	0.0	0.0	0.0
1.2.3.2.1	CREW HABITABILITY MODULE-CHM	0.0	0.0	0.0	0.0
1.2.3.2.2	CONSUMABLES LOGISTICS MODULE-CLM	0.0	0.0	0.0	0.0
1.2.3.3	OPERATIONS	0.0	0.0	0.0	0.0
1.2.3.3.1	SATELLITE OPERATIONS CREW - SCB	0.0	0.0	0.0	0.0
1.2.3.3.2	SATELLITE OPERATIONS CREW - MMB	0.0	0.0	0.0	0.0
1.2.3.3.3	CREW PROVISIONS - SCB	0.0	0.0	0.0	0.0
1.2.3.3.4	O&M CREW PROVISIONS - MMB	0.0	0.0	0.0	0.0
1.3	TRANSPORTATION	1989.518	63.481	0.0	63.481
1.3.1	SPS-HEAVY LIFT LAUNCH VEHICLE(HLLV)	1662.568	56.480	0.0	56.480
1.3.1.1	SPS-HLLV FLEET	1121.661	56.480	0.0	56.480
1.3.1.2	SPS-HLLV OPERATIONS (VTO-HL)	540.906	0.0	0.0	0.0
1.3.2	CARGO ORBITAL TRANSFER VEHICLE(COTV)	204.284	2.938	0.0	2.938
1.3.2.1	COTV VEHICLES	199.257	2.938	0.0	2.938

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE B-10. SATELLITE POWER SYSTEM (SPS) PROGRAM PRE-IOC COSTS

WBS #	DESCRIPTION	AVERAGE INV PER SAT	****PRE-IOC ********* OPS COST PER SAT/YR RCI-PRE	U&M-PRE	TOTAL PRE-IOC
1.3.2.1.1	PRIMARY STRUCTURE	0.640	0.0	0.0	0.0
1.3.2.1.2	SECONDARY STRUCTURE	13.721	0.046	0.0	0.046
1.3.2.1.3	MECHANISMS - EOTV	1.131	0.0	0.0	0.0
1.3.2.1.4	TRACKS AND ACCESSWAYS	0.047	0.0	0.0	0.0
1.3.2.1.5	CONCENTRATOR	0.803	0.003	0.0	0.003
1.3.2.1.6	SOLAR BLANKET	21.810	0.073	0.0	0.073
1.3.2.1.7	SWITCHGEAR AND REGULATORS	0.542	0.002	0.0	0.002
1.3.2.1.8	LO-VOLTAGE CONVERTERS	0.045	0.000	0.0	0.000
1.3.2.1.9	CONDUCTORS AND INSULATION	0.331	0.0	0.0	0.0
1.3.2.1.10	BATTERIES	75.869	2.529	0.0	2.529
1.3.2.1.11	BATTERY PD&C	3.188	0.016	0.0	0.016
1.3.2.1.12	ACS HARDWARE-COTV	75.166	0.251	0.0	0.251
1.3.2.1.13	INFO. MGMT. AND CONTROL	5.966	0.020	0.0	0.020
1.3.2.2	COTV OPERATIONS	5.027	0.0	0.0	0.0
1.3.3	STS PERSONNEL CARGO LAUNCH VEHICLE	50.379	0.0	0.0	0.0
1.3.3.1	STS CARGO CARRIER AND EM	10.130	0.0	0.0	0.0
1.3.3.2	STS OPERATIONS - GROWTH AND DERIVATI	40.249	0.0	0.0	0.0
1.3.3.2.1	OPERATIONS-STS GROWTH HLLV	24.300	0.0	0.0	0.0
1.3.3.2.2	OPERATIONS - STS DERIVATIVE	15.949	0.0	0.0	0.0
1.3.4	PERSONNEL ORBITAL TRANS VEHICLE	3.663	0.190	0.0	0.190
1.3.4.1	POTV-FLEET	2.845	0.190	0.0	0.190
1.3.4.2	POTV-OPERATIONS	0.818	0.0	0.0	0.0
1.3.5	PERSONNEL MODULE(PM)	3.963	0.331	0.0	0.331
1.3.5.1	PM FLEET	3.307	0.331	0.0	0.331
1.3.5.2	PM OPERATIONS	0.656	0.0	0.0	0.0
1.3.6	INTRAORBITAL TRANSFER VEHICLE(IOTV)	2.359	0.151	0.0	0.151
1.3.6.1	IOTV FLEET	2.262	0.151	0.0	0.151
1.3.6.2	IOTV OPERATIONS	0.097	0.0	0.0	0.0
1.3.7	GROUND SUPPORT FACILITIES	62.302	3.392	0.0	3.392
1.3.7.1	LAUNCH FACILITIES	0.0	0.0	0.0	0.0
1.3.7.2	RECOVERY FACILITIES	0.0	0.0	0.0	0.0
1.3.7.3	FUEL FACILITIES	0.0	0.0	0.0	0.0
1.3.7.4	LOGISTICS SUPPORT	0.0	0.0	0.0	0.0
1.3.7.5	OPERATIONS	0.0	0.0	0.0	0.0
1.4	GROUND RECEIVING STATION	4217.105	0.087	1.570	1.657

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE B-10. SATELLITE POWER SYSTEM (SPS) PROGRAM PRE-IOC COSTS

WBS #	DESCRIPTION	AVERAGE INV PER SAT	****PRE-IOC OPS COST PER SAT/YR RC1-PRE	********* O&M-PRE	TOTAL PRE-IOC
1.4.1	SITE AND FACILITIES	221.053	0.0	0.0	0.0
1.4.1.1	LAND AND PREPARATION	115.969	0.0	0.0	0.0
1.4.1.1.1	LAND	40.950	0.0	0.0	0.0
1.4.1.1.2	LAND PREPARATION	75.019	0.0	0.0	0.0
1.4.1.2	ROADS AND FENCES	86.742	0.0	0.0	0.0
1.4.1.2.1	RAILS AND ROADS	86.241	0.0	0.0	0.0
1.4.1.2.2	FENCING	0.501	0.0	0.0	0.0
1.4.1.3	UTILITIES	0.234	0.0	0.0	0.0
1.4.1.4	BUILDINGS	13.428	0.0	0.0	0.0
1.4.1.4.1	STORAGE,MAINTENANCE FACILITIES	1.521	0.0	0.0	0.0
1.4.1.4.2	CONV. STA. & MONITOR/CONTROL FAC.	11.907	0.0	0.0	0.0
1.4.1.5	MAINTENANCE EQPT. FOR SITE & FACILIT	4.680	0.0	0.0	0.0
1.4.1.6	LIGHTNING PROTECTION	0.0	0.0	0.0	0.0
1.4.1.7	SITE & FACILITIES DDT&E	0.0	0.0	0.0	0.0
1.4.2	RECTENNA SUPPORT STRUCTURE	2138.878	0.087	1.570	1.657
1.4.2.1	STEEL PANEL FAB. & INSTALLATION	1985.017	0.0	0.0	0.0
1.4.2.1.1	HAT SECTIONS	420.412	0.0	0.0	0.0
1.4.2.1.2	WIDE FLANGES	345.349	0.0	0.0	0.0
1.4.2.1.3	TUBE BRACES & HARDWARE	504.671	0.0	0.0	0.0
1.4.2.1.4	ASSEMBLY & INSTALLATION	714.585	0.0	0.0	0.0
1.4.2.2	TRENCHING & CONCRETE INSTALLATION	153.862	0.087	1.570	1.657
1.4.2.2.1	FOOTING CONCRETE & RE-BAR	82.860	0.0	0.0	0.0
1.4.2.2.2	MACHINGERY & EQUIPMENT - GRS CONSTRU	0.872	0.087	1.570	1.657
1.4.2.2.3	CONSTRUCTION OPERATIONS	70.130	0.0	0.0	0.0
1.4.2.3	SUPPORT STRUCTURE DDT&E	0.0	0.0	0.0	0.0
1.4.3	POWER COLLECTION	1583.244	0.0	0.0	0.0
1.4.3.1	ANTENNA ARRAY ELEMENTS	1318.966	0.0	0.0	0.0
1.4.3.2	POWER DISTRIBUTION SYSTEM	81.501	0.0	0.0	0.0
1.4.3.3	INSTALLATION & CHECKOUT	182.777	0.0	0.0	0.0
1.4.3.4	POWER COLLECTION-DDT&E	0.0	0.0	0.0	0.0
1.4.4	CONTROL	87.750	0.0	0.0	0.0
1.4.4.1	CONTROL CENTER EQUIPMENT	17.550	0.0	0.0	0.0
1.4.4.2	CONTROL ELECTRONICS	70.200	0.0	0.0	0.0
1.4.4.3	CONTROL DDT&E	0.0	0.0	0.0	0.0
1.4.5	GRID INTERFACE	186.181	0.0	0.0	0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE SATELLITE POWER SYSTEM (SPS) PROGRAM PRE-IOC COSTS

			****PRE-IOC *********		
		AVERAGE	OPS COST PER SAT/YR		TOTAL
WBS #	DESCRIPTION	INV PER SAT	RCI-PRE	O&M-PRE	PRE-IOC
1.4.5.1	ELECTRICAL EQUIPMENT	186.181	0.0	0.0	0.0
1.4.5.2	GRID INTERFACE-DDT&E	0.0	0.0	0.0	0.0
1.4.6	OPERATIONS	0.0	0.0	0.0	0.0
1.4.6.1	OPER. & MAINT. PERSONNEL	0.0	0.0	0.0	0.0
1.4.6.2	MAINT. MATERIAL	0.0	0.0	0.0	0.0
1.5	MANAGEMENT AND INTEGRATION	569.734	3.395	0.264	3.659
1.6	MASS CONTINGENCY	778.208	0.650	0.557	1.207

B.4.3 SPS POST-IOC OPERATIONS

Post-IOC operations cost includes replacement capital of systems, facilities and equipment, plus those expenditures incurred in the day-to-day operational activities beginning with SPS-IOC and continuing over the life of each SPS. Examples of RCI costs in this category are spares, their installation and transportation charges, plus permanent improvements in major systems. O&M costs cover such things as wages of maintenance personnel, minor repairs and adjustments to maintain system operation, and the transportation cost of personnel along with expendable and consumables.

Table B-11 presents a summary of operations cost in this category. These estimates cover post-IOC periods and are identified as average annual expenditures for each SPS. Replacement capital is required primarily for the satellite system, operational support facilities and transportation vehicles. O&M expenditures are needed to support 1) mobile maintenance bases that service the satellite, 2) space transportation systems for transfer of mass to orbit, and 3) personnel/maintenance materials needed at the ground receiving station.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE B-11. SATELLITE POWER SYSTEM (SPS) PROGRAM POST-IOC COSTS

WBS #	DESCRIPTION	***POST-IOC ********* OPS COST PER SAT/YR RCI-POST	O&M-POST	TOTAL POST-IOC
1	SATELLITE POWER SYSTEM (SPS) PROGRAM	73.828	71.146	144.974
1.1	SATELLITE SYSTEM	33.025	0.720	33.745
1.1.1	ENERGY CONVERSION - SATELLITE	7.512	0.026	7.538
1.1.1.1	STRUCTURE	0.161	0.015	0.176
1.1.1.1.1	PRIMARY STRUCTURE	0.0	0.0	0.0
1.1.1.1.2	SECONDARY STRUCTURE	0.152	0.0	0.152
1.1.1.1.3	MECHANISMS	0.009	0.015	0.024
1.1.1.2	CONCENTRATORS	0.092	0.0	0.092
1.1.1.3	SOLAR BLANKETS	4.258	0.0	4.258
1.1.1.4	POWER DIST. & CONDITIONING	2.715	0.011	2.726
1.1.1.4.1	SWITCH GEAR & REGULATORS - E.C.	2.503	0.0	2.503
1.1.1.4.2	LO-VOLTAGE CONVERTERS - E.C.	0.122	0.0	0.122
1.1.1.4.3	CONDUCTORS & INSULATION	0.0	0.0	0.0
1.1.1.4.4	SLIP RINGS	0.076	0.0	0.076
1.1.1.4.5	BATTERIES	0.007	0.011	0.018
1.1.1.4.6	BATTERY PD&C	0.007	0.0	0.007
1.1.1.5	THERMAL CONTROL	0.0	0.0	0.0
1.1.1.6	MAINTENANCE	0.285	0.0	0.285
1.1.1.6.1	MAINTENANCE - FREE FLYERS	0.188	0.0	0.188
1.1.1.6.2	MANNED MANIPULATOR	0.098	0.0	0.098
1.1.1.6.3	TRACKS & ACCESS WAYS	0.0	0.0	0.0
1.1.2	POWER TRANSMISSION - SATELLITE	24.431	0.569	25.000
1.1.2.1	STRUCTURE	0.213	0.015	0.228
1.1.2.1.1	PRIMARY STRUCTURE	0.0	0.0	0.0
1.1.2.1.2	SECONDARY STRUCTURE	0.210	0.0	0.210
1.1.2.1.3	MECHANISMS (TRUNNIONS)	0.003	0.015	0.018
1.1.2.2	TRANSMITTER SUBARRAYS - KLYSTRONS	11.479	0.0	11.479
1.1.2.2.1	KLYSTRON MPT & RS DDT&E	0.0	0.0	0.0
1.1.2.2.2	WAVE GUIDE	0.0	0.0	0.0
1.1.2.2.3	HEAT PIPES -THERMAL	0.0	0.0	0.0
1.1.2.2.4	KLYSTRON POWER MODULE ELEMENT	1.793	0.0	1.793
1.1.2.2.5	PHASE SHIFTERS	4.822	0.0	4.822
1.1.2.2.6	PHASE CONTROL ELECTRONICS	4.196	0.0	4.196
1.1.2.2.7	POWER DIVIDERS & COMBINERS	0.668	0.0	0.668
1.1.2.2.8	MW SYSTEM INTEGRATION	0.0	0.0	0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION, 1980

TABLE B-11. SATELLITE POWER SYSTEM (SPS) PROGRAM POST-IOC COSTS

WBS #	DESCRIPTION	***POST-IOC ********* OPS COST PER SAT/YR RCI-POST	O&M-POST	TOTAL POST-IOC
1.1.2.3	POWER DIST. & CONDITIONING	12.039	0.543	12.581
1.1.2.3.1	SWITCH GEAR & REGULATORS	2.527	0.0	2.527
1.1.2.3.2	HI-VOLTAGE CONVERTERS	8.988	0.0	8.988
1.1.2.3.3	LO-VOLTAGE CONVERTERS	0.039	0.0	0.039
1.1.2.3.4	CONDUCTORS & INSULATION	0.0	0.0	0.0
1.1.2.3.5	BATTERIES	0.349	0.543	0.891
1.1.2.3.6	BATTERY P&C	0.137	0.0	0.137
1.1.2.4	THERMAL CONTROL - INSULATION	0.0	0.0	0.0
1.1.2.5	CONTROL - PHASE REFERENCE	0.307	0.012	0.319
1.1.2.5.1	REFERENCE FREQUENCY GENERATOR	0.004	0.012	0.016
1.1.2.5.2	DIST. SYSTEM, COAXIAL CABLE	0.0	0.0	0.0
1.1.2.5.3	DIST. SYSTEM, DEVICES	0.303	0.0	0.303
1.1.2.6	MAINTENANCE	0.394	0.0	0.394
1.1.2.6.1	MAINTENANCE - FREE FLYERS	0.222	0.0	0.222
1.1.2.6.2	GANTRY CRANE	0.0	0.0	0.0
1.1.2.6.3	ON-CRANE CONTROL CENTER	0.172	0.0	0.172
1.1.2.6.4	TRACKS & ACCESS WAYS	0.0	0.0	0.0
1.1.3	INFORMATION MGMT. & CONTROL - SATELL	0.631	0.0	0.631
1.1.3.1	MASTER CONTROL COMPUTER	0.010	0.0	0.010
1.1.3.2	DISPLAYS & CONTROLS	0.002	0.0	0.002
1.1.3.3	SUPERVISORY COMPUTER	0.004	0.0	0.004
1.1.3.4	REMOTE COMPUTER	0.009	0.0	0.009
1.1.3.5	BUS CONTROL UNIT	0.020	0.0	0.020
1.1.3.6	MICROPROCESSORS	0.019	0.0	0.019
1.1.3.7	REMOTE ACQUISITION & CONTROL	0.021	0.0	0.021
1.1.3.8	SUBMULTIPLEXORS	0.228	0.0	0.228
1.1.3.9	INSTRUMENTATION	0.264	0.0	0.264
1.1.3.10	OPTICAL FIBER	0.002	0.0	0.002
1.1.3.11	CABLES/HARNESS	0.051	0.0	0.051
1.1.4	ATTITUDE CONTROL & STATIONKEEPING -S	0.233	0.100	0.333
1.1.4.1	ACS HARDWARE	0.233	0.0	0.233
1.1.4.1.1	ACS THRUSTER COMPONENTS	0.233	0.0	0.233
1.1.4.1.2	ACS - CONDUCTORS & INSULATION	0.0	0.0	0.0
1.1.4.1.3	ACS - POWER PROCESSING EQUIPMENT	0.0	0.0	0.0
1.1.4.1.4	ACS - THRUSTER GIMBALS AND MOUNTING	0.0	0.0	0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE B-11. SATELLITE POWER SYSTEM (SPS) PROGRAM POST-IOC COSTS

WBS #	DESCRIPTION	***POST-IOC ********* OPS COST PER SAT/YR RCI-POST	O&M-POST	TOTAL POST-IOC
1.1.4.2	ACSS PROPELLANT	0.0	0.100	0.100
1.1.5	COMMUNICATIONS - SATELLITE	0.0	0.0	0.0
1.1.5.1	SATELLITE TO GROUND	0.0	0.0	0.0
1.1.5.2	SATELLITE TO RESUPPLY VEHICLES	0.0	0.0	0.0
1.1.5.3	SATELLITE INTERCOM	0.0	0.0	0.0
1.1.6	INTERFACE - SATELLITE	0.218	0.025	0.243
1.1.6.1	STRUCTURE	0.010	0.0	0.010
1.1.6.1.1	PRIMARY STRUCTURE	0.0	0.0	0.0
1.1.6.1.2	SECONDARY STRUCTURE	0.010	0.0	0.010
1.1.6.2	MECHANISMS - INTERFACE	0.038	0.025	0.063
1.1.6.3	POWER DISTRIBUTION	0.012	0.0	0.012
1.1.6.3.1	CONDUCTOR & INSULATION	0.0	0.0	0.0
1.1.6.3.2	SLIP RING BRUSHES	0.012	0.0	0.012
1.1.6.4	THERMAL CONTROL	0.0	0.0	0.0
1.1.6.5	MAINTENANCE	0.158	0.0	0.158
1.1.6.5.1	MAINTENANCE - FREE FLYERS	0.041	0.0	0.041
1.1.6.5.2	MANNED MANIPULATOR	0.117	0.0	0.117
1.1.6.5.3	TRACKS & ACCESS WAYS	0.0	0.0	0.0
1.1.7	SYSTEMS TEST - SATELLITE	0.0	0.0	0.0
1.1.7.1	SYSTEM GROUND TEST HARDWARE	0.0	0.0	0.0
1.1.7.2	SYSTEM GROUND TEST OPERATIONS	0.0	0.0	0.0
1.1.8	GROUND SUPPORT EQUIPMENT- SATELLITE	0.0	0.0	0.0
1.1.9	PROOF-OF-CONCEPT PILOT PLANT	0.0	0.0	0.0
1.1.9.1	COTV PRECURSOR VEHICLE	0.0	0.0	0.0
1.1.9.1.1	PRIMARY STRUCTURE - E.C.	0.0	0.0	0.0
1.1.9.1.2	SECONDARY STRUCTURE - E.C.	0.0	0.0	0.0
1.1.9.1.3	MECHANISMS - PRECURSOR E.C.	0.0	0.0	0.0
1.1.9.1.4	CONCENTRATOR - E.C.	0.0	0.0	0.0
1.1.9.1.5	SOLAR BLANKET -E.C.	0.0	0.0	0.0
1.1.9.1.6	SWITCHGEAR & REGULATORS - E.C.	0.0	0.0	0.0
1.1.9.1.7	LO-VOLTAGE CONVERTERS - E.C	0.0	0.0	0.0
1.1.9.1.8	CONDUCTORS & INSULATION - E.C.	0.0	0.0	0.0
1.1.9.1.9	ACS HARDWARE - E.C.	0.0	0.0	0.0
1.1.9.1.10	ACS - CONDUCTORS & INSUL - E.C.	0.0	0.0	0.0
1.1.9.1.11	ACS - BATTERIES - E.C.	0.0	0.0	0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE B-11. SATELLITE POWER SYSTEM (SPS) PROGRAM POST-IOC COSTS

WBS #	DESCRIPTION	***POST-IOC ********* OPS COST PER SAT/YR RCI-POST	O&M-POST	TOTAL POST-IOC
1.1.9.1.12	ACS - BATTERY PD&C - E.C.	0.0	0.0	0.0
1.1.9.1.13	SLIPRINGS - PRECURSOR E.C.	0.0	0.0	0.0
1.1.9.1.14	TRACKS & ACCESS WAYS - E.C.	0.0	0.0	0.0
1.1.9.1.15	PRIMARY STRUCTURE - INTERFACE	0.0	0.0	0.0
1.1.9.1.16	SECONDARY STRUCTURE - INTERFACE	0.0	0.0	0.0
1.1.9.1.17	MECHANISMS - INTERFACE	0.0	0.0	0.0
1.1.9.1.18	CONDUCTORS & INSULATION - INTERFACE	0.0	0.0	0.0
1.1.9.1.19	SLIPRING BRUSHES - PRECURSOR - INTER	0.0	0.0	0.0
1.1.9.1.20	PRIMARY STRUCTURE - POWER TRANS	0.0	0.0	0.0
1.1.9.1.21	SECONDARY STRUCTURE - POWER TRANS	0.0	0.0	0.0
1.1.9.1.22	MECHANISMS - POWER TRANS.	0.0	0.0	0.0
1.1.9.1.23	P.T. KLYSTRON SUBARRAY DDT&E	0.0	0.0	0.0
1.1.9.1.24	P.T. KLYSTRON WAVEGUIDE	0.0	0.0	0.0
1.1.9.1.25	P.T. KLYSTRON HEATPIPES	0.0	0.0	0.0
1.1.9.1.26	P.T. KLYSTRON P.M. ELEMENT	0.0	0.0	0.0
1.1.9.1.27	P.T. KLYSTRON PHASE SHIFTERS	0.0	0.0	0.0
1.1.9.1.28	P. T. KLYSTRON PH. CONTROL ELECTRONI	0.0	0.0	0.0
1.1.9.1.29	P. T. KLYSTRON POWER DIVIDERS AND CO	0.0	0.0	0.0
1.1.9.1.30	KLYSTRON SUBARRAY SYSTEM INTEGRATION	0.0	0.0	0.0
1.1.9.1.31	PD&C - SW. GR. & REGULATORS - P.T.	0.0	0.0	0.0
1.1.9.1.32	PD&C - HI VOLTAGE CONVERT - P.T.	0.0	0.0	0.0
1.1.9.1.33	PD&C - LO VOLTAGE CONVERT - P.T.	0.0	0.0	0.0
1.1.9.1.34	PD&C CONDUCTORS & INSULATION - P. T.	0.0	0.0	0.0
1.1.9.1.35	BATTERIES - P.T. PRECURSOR	0.0	0.0	0.0
1.1.9.1.36	P.T. - BATTERY PD&C	0.0	0.0	0.0
1.1.9.1.37	THERMAL CONTROL - INSULATION - PRECU	0.0	0.0	0.0
1.1.9.1.38	REFERENCE FREQUENCY GENERATOR - PREC	0.0	0.0	0.0
1.1.9.1.39	DIST. SYSTEM, COAXIAL CABLE	0.0	0.0	0.0
1.1.9.1.40	DIST. SYSTEM DEVICES	0.0	0.0	0.0
1.1.9.1.41	P.T. - MASTER CONTROL COMPUTER - IMS	0.0	0.0	0.0
1.1.9.1.42	P.T. BUS CONTROL UNIT	0.0	0.0	0.0
1.1.9.1.43	P.T. - MICROPROCESSORS - IMS/COM	0.0	0.0	0.0
1.1.9.1.44	P.T. - REMOTE ACQ & CONTROL - IMS/CO	0.0	0.0	0.0
1.1.9.1.45	P.T. - SUBMULTIPLEXER - IMS/COM	0.0	0.0	0.0
1.1.9.1.46	P.T. - INSTRUMENTATION - IMS/COM	0.0	0.0	0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION, 1980

TABLE B-11. SATELLITE POWER SYSTEM (SPS) PROGRAM POST-IOC COSTS

WBS #	DESCRIPTION	***POST-IOC ********* OPS COST PER SAT/YR RCI-POST	O&M-POST	TOTAL POST-IOC
1.1.9.1.47	P.T. - CABLES & HARNESS - IMS/COM	0.0	0.0	0.0
1.1.9.1.48	P.T. TRACKS AND ACCESSWAYS FOR MW AN	0.0	0.0	0.0
1.1.9.1.49	P.T. ANT. MW LIFTS - INSTALL & C/O E	0.0	0.0	0.0
1.1.9.2	PRECURSOR OPERATIONS	0.0	0.0	0.0
1.1.9.2.1	PRECURSOR STS TRANSPORTATION	0.0	0.0	0.0
1.1.9.2.2	PRECURSOR CONSTRUCTION CREW	0.0	0.0	0.0
1.1.9.2.3	PRECURSOR GEO TEST ACTIVITY	0.0	0.0	0.0
1.1.9.2.4	PRECURSOR PROPELLANT	0.0	0.0	0.0
1.1.9.3	PRECURSOR GROUND RECEIVING FACILITY	0.0	0.0	0.0
1.2	SPACE CONSTRUCTION & SUPPORT	15.134	15.628	30.762
1.2.1	CONSTRUCTION FACILITIES	0.0	0.0	0.0
1.2.1.1	WORK SUPPORT FACILITIES	0.0	0.0	0.0
1.2.1.1.1	BEAM MACHINE	0.0	0.0	0.0
1.2.1.1.2	BEAM MACHINE CASSETTES SET	0.0	0.0	0.0
1.2.1.1.3	CABLE ATTACHMENT MACHINE	0.0	0.0	0.0
1.2.1.1.4	REMOTE MANIPULATOR	0.0	0.0	0.0
1.2.1.1.5	BLANKET DISPENSER MACHINE	0.0	0.0	0.0
1.2.1.1.6	SOLAR BLANKET CASSETTES	0.0	0.0	0.0
1.2.1.1.7	REFLECTOR DISPENSER MACHINE	0.0	0.0	0.0
1.2.1.1.8	REFLECTOR CASSETTES	0.0	0.0	0.0
1.2.1.1.9	CABLE/CATENARY DISPENSER MACHINES	0.0	0.0	0.0
1.2.1.1.10	ANTENNA PANEL INS. EQPT.	0.0	0.0	0.0
1.2.1.1.11	GANTRY/CRANES	0.0	0.0	0.0
1.2.1.1.12	CARGO STORAGE DEPOTS	0.0	0.0	0.0
1.2.1.1.13	FAB FIXTURE	0.0	0.0	0.0
1.2.1.1.14	AIRLOCK DOCKING MODULE (ADM)	0.0	0.0	0.0
1.2.1.1.15	BASE MGMT. MODULE (BMM)	0.0	0.0	0.0
1.2.1.1.16	POWER MODULE (PM)	0.0	0.0	0.0
1.2.1.1.17	PRESSURIZED STORAGE MODULE (PSM)	0.0	0.0	0.0
1.2.1.2	CREW SUPPORT FACILITIES-SCB	0.0	0.0	0.0
1.2.1.2.1	AIRLOCK DOCKING MODULE-ADM	0.0	0.0	0.0
1.2.1.2.2	CREW HABITABILITY MODULE-CHM	0.0	0.0	0.0
1.2.1.2.3	CONSUMABLES LOGISTICS MODULE-CLM	0.0	0.0	0.0
1.2.1.2.4	SHIELDING	0.0	0.0	0.0
1.2.1.2.5	CREW SUPPORT MODULE-CSM	0.0	0.0	0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE B-11. SATELLITE POWER SYSTEM (SPS) PROGRAM POST-IOC COSTS

WBS *	DESCRIPTION	***POST-IOC ********* UPS COST PER SAT/YR RCI-POST	O&M-POST	TOTAL POST-IOC
1.2.1.3	OPERATIONS	0.0	0.0	0.0
1.2.1.3.1	OPERATIONS, CONSTRUCTION CREW	0.0	0.0	0.0
1.2.1.3.2	ORBITAL OPERATIONS,CONST. PROV.	0.0	0.0	0.0
1.2.2	LOGISTICS SUPPORT FACILITIES-LEO	0.119	0.130	0.250
1.2.2.1	WORK SUPPORT FACILITIES	0.077	0.077	0.155
1.2.2.1.1	BASE MGMT. MODULE-BMM	0.040	0.040	0.080
1.2.2.1.2	POWER MODULE-PM	0.035	0.035	0.071
1.2.2.1.3	AIRLOCK DOCKING MODULE - ADM	0.002	0.002	0.004
1.2.2.2	CREW SUPPORT FACILITIES	0.042	0.042	0.084
1.2.2.2.1	CREW HABITABILITY MODULE-CHM	0.013	0.013	0.026
1.2.2.2.2	CONSUMABLES LOGISTICS MODULE CLM	0.009	0.009	0.018
1.2.2.2.3	CREW SUPPORT MODULE/EVA	0.020	0.020	0.040
1.2.2.3	OPERATIONS	0.0	0.011	0.011
1.2.2.3.1	LEO OPERATIONS CREW	0.0	0.007	0.007
1.2.2.3.2	LEO CREW PROVISIONS	0.0	0.003	0.003
1.2.3	O&M SUPPORT FACILITIES - SATELLITE	15.015	15.497	30.512
1.2.3.1	WORK SUPPORT FACILITIES	14.170	14.170	28.340
1.2.3.1.1	AIRLOCK DOCKING MODULE-ADM	0.110	0.110	0.220
1.2.3.1.2	BASE MGMT MODULE-BMM	11.537	11.537	23.073
1.2.3.1.3	PRESSURIZED STORAGE MODULE-PSM	0.516	0.516	1.031
1.2.3.1.4	POWER MODULE-PM	2.007	2.008	4.015
1.2.3.2	CREW SUPPORT FACILITIES	0.845	0.845	1.690
1.2.3.2.1	CREW HABITABILITY MODULE-CHM	0.501	0.501	1.001
1.2.3.2.2	CONSUMABLES LOGISTICS MODULE-CLM	0.344	0.344	0.689
1.2.3.3	OPERATIONS	0.0	0.482	0.482
1.2.3.3.1	SATELLITE OPERATIONS CREW - SCB	0.0	0.039	0.039
1.2.3.3.2	SATELLITE OPERATIONS CREW - MMB	0.0	0.292	0.292
1.2.3.3.3	CREW PROVISIONS - SCB	0.0	0.018	0.018
1.2.3.3.4	O&M CREW PROVISIONS - MMB	0.0	0.133	0.133
1.3	TRANSPORTATION	15.039	17.419	32.459
1.3.1	SPS-HEAVY LIFT LAUNCH VEHICLE(HLLV)	13.377	13.150	26.527
1.3.1.1	SPS-HLLV FLEET	13.377	8.855	22.232
1.3.1.2	SPS-HLLV OPERATIONS (VTO-HL)	0.0	4.294	4.294
1.3.2	CARGO ORBITAL TRANSFER VEHICLE(COTV)	0.735	2.109	2.844
1.3.2.1	COTV VEHICLES	0.735	2.071	2.806

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE B-11. SATELLITE POWER SYSTEM (SPS) PROGRAM POST-IOC COSTS

WBS #	DESCRIPTION	***POST-IOC ********* OPS COST PER SAT/YR RCI-POST	O&M-POST	TOTAL POST-IOC
1.3.2.1.1	PRIMARY STRUCTURE	0.0	0.005	0.005
1.3.2.1.2	SECONDARY STRUCTURE	0.011	0.114	0.126
1.3.2.1.3	MECHANISMS - EOTV	0.0	0.009	0.009
1.3.2.1.4	TRACKS AND ACCESSWAYS	0.0	0.000	0.000
1.3.2.1.5	CONCENTRATOR	0.001	0.007	0.007
1.3.2.1.6	SOLAR BLANKET	0.018	0.182	0.200
1.3.2.1.7	SWITCHGEAR AND REGULATORS	0.000	0.005	0.005
1.3.2.1.8	LO-VOLTAGE CONVERTERS	0.000	0.000	0.000
1.3.2.1.9	CONDUCTORS AND INSULATION	0.0	0.003	0.003
1.3.2.1.10	BATTERIES	0.632	1.043	1.675
1.3.2.1.11	BATTERY PD&C	0.004	0.027	0.031
1.3.2.1.12	ACS HARDWARE-COTV	0.063	0.626	0.689
1.3.2.1.13	INFO. MGMT. AND CONTROL	0.005	0.050	0.055
1.3.2.2	COTV OPERATIONS	0.0	0.038	0.038
1.3.3	STS PERSONNEL CARGO LAUNCH VEHICLE	0.0	0.0	0.0
1.3.3.1	STS CARGO CARRIER AND EM	0.0	0.0	0.0
1.3.3.2	STS OPERATIONS - GROWTH AND DERIVATI	0.0	0.0	0.0
1.3.3.2.1	OPERATIONS-STS GROWTH HLLV	0.0	0.0	0.0
1.3.3.2.2	OPERATIONS - STS DERIVATIVE	0.0	0.0	0.0
1.3.4	PERSONNEL ORBITAL TRANS VEHICLE	0.047	0.031	0.078
1.3.4.1	POTV-FLEET	0.047	0.024	0.071
1.3.4.2	POTV-OPERATIONS	0.0	0.007	0.007
1.3.5	PERSONNEL MODULE(PM)	0.083	0.034	0.117
1.3.5.1	PM FLEET	0.083	0.028	0.110
1.3.5.2	PM OPERATIONS	0.0	0.006	0.006
1.3.6	INTRAORBITAL TRANSFER VEHICLE(IOTV)	0.036	0.019	0.055
1.3.6.1	IOTV FLEET	0.036	0.018	0.055
1.3.6.2	IOTV OPERATIONS	0.0	0.001	0.001
1.3.7	GROUND SUPPORT FACILITIES	0.761	2.077	2.838
1.3.7.1	LAUNCH FACILITIES	0.0	0.0	0.0
1.3.7.2	RECOVERY FACILITIES	0.0	0.0	0.0
1.3.7.3	FUEL FACILITIES	0.0	0.0	0.0
1.3.7.4	LOGISTICS SUPPORT	0.0	0.0	0.0
1.3.7.5	OPERATIONS	0.0	0.0	0.0
1.4	GROUND RECEIVING STATION	0.234	31.656	31.890

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE B-11. SATELLITE POWER SYSTEM (SPS) PROGRAM POST-IOC COSTS

WBS #	DESCRIPTION	***POST-IOC ********* OPS COST PER SAT/YR RCI-POST	O&M-POST	TOTAL POST-IOC
1.4.1	SITE AND FACILITIES	0.234	0.094	0.328
1.4.1.1	LAND AND PREPARATION	0.0	0.0	0.0
1.4.1.1.1	LAND	0.0	0.0	0.0
1.4.1.1.2	LAND PREPARATION	0.0	0.0	0.0
1.4.1.2	ROADS AND FENCES	0.0	0.0	0.0
1.4.1.2.1	RAILS AND ROADS	0.0	0.0	0.0
1.4.1.2.2	FENCING	0.0	0.0	0.0
1.4.1.3	UTILITIES	0.0	0.0	0.0
1.4.1.4	BUILDINGS	0.0	0.0	0.0
1.4.1.4.1	STORAGE,MAINTENANCE FACILITIES	0.0	0.0	0.0
1.4.1.4.2	CONV. STA. & MONITOR/CONTROL FAC.	0.0	0.0	0.0
1.4.1.5	MAINTENANCE EQPT. FOR SITE & FACILIT	0.234	0.094	0.328
1.4.1.6	LIGHTNING PROTECTION	0.0	0.0	0.0
1.4.1.7	SITE & FACILITIES DDT&E	0.0	0.0	0.0
1.4.2	RECTENNA SUPPORT STRUCTURE	0.0	0.0	0.0
1.4.2.1	STEEL PANEL FAB. & INSTALLATION	0.0	0.0	0.0
1.4.2.1.1	HAT SECTIONS	0.0	0.0	0.0
1.4.2.1.2	WIDE FLANGES	0.0	0.0	0.0
1.4.2.1.3	TUBE BRACES & HARDWARE	0.0	0.0	0.0
1.4.2.1.4	ASSEMBLY & INSTALLATION	0.0	0.0	0.0
1.4.2.2	TRENCHING & CONCRETE INSTALLATION	0.0	0.0	0.0
1.4.2.2.1	FOOTING CONCRETE & RE-BAR	0.0	0.0	0.0
1.4.2.2.2	MACHINGERY & EQUIPMENT - GRS CONSTRU	0.0	0.0	0.0
1.4.2.2.3	CONSTRUCTION OPERATIONS	0.0	0.0	0.0
1.4.2.3	SUPPORT STRUCTURE DDT&E	0.0	0.0	0.0
1.4.3	POWER COLLECTION	0.0	0.0	0.0
1.4.3.1	ANTENNA ARRAY ELEMENTS	0.0	0.0	0.0
1.4.3.2	POWER DISTRIBUTION SYSTEM	0.0	0.0	0.0
1.4.3.3	INSTALLATION & CHECKOUT	0.0	0.0	0.0
1.4.3.4	POWER COLLECTION-DDT&E	0.0	0.0	0.0
1.4.4	CONTROL	0.0	0.0	0.0
1.4.4.1	CONTROL CENTER EQUIPMENT	0.0	0.0	0.0
1.4.4.2	CONTROL ELECTRONICS	0.0	0.0	0.0
1.4.4.3	CONTROL DDT&E	0.0	0.0	0.0
1.4.5	GRID INTERFACE	0.0	0.0	0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE B-11. SATELLITE POWER SYSTEM (SPS) PROGRAM POST-IOC COSTS

WBS #	DESCRIPTION	***POST-IOC OPS COST PER SAT/YR RCI-POST	********* O&M-POST	TOTAL POST-IOC
1.4.5.1	ELECTRICAL EQUIPMENT	0.0	0.0	0.0
1.4.5.2	GRID INTERFACE-UDTGE	0.0	0.0	0.0
1.4.6	OPERATIONS	0.0	31.562	31.562
1.4.6.1	OPER. & MAINT. PERSONNEL	0.0	16.200	16.200
1.4.6.2	MAINT. MATERIAL	0.0	15.362	15.362
1.5	MANAGEMENT AND INTEGRATION	3.172	3.271	6.443
1.6	MASS CONTINGENCY	7.224	2.452	9.676

1.0 SATELLITE POWER SYSTEM (SPS) PROGRAM COST ESTIMATES

This section of the appendix volume contains information on the identification of cost estimates for each of the approximately 300 line items within the SPS work breakdown structure. It includes cost for DDT&E, TFU, investment, and operational phase of the program covering satellite, space construction, transportation, and ground receiving station elements. Information within this volume emphasizes Rockwell's SPS reference concept—a 3-trough/planar/klystron configuration and in some instances, cost detail is provided on WBS line items of the other 4 SPS concepts to emphasize system variations within these configurations.

The Satellite Power Systems (SPS) concept is based upon a large photovoltaic power collection satellite located in a Geosynchronous, Equatorial Orbit (GEO) utilizing a microwave power transmission concept to transmit the collected energy to Ground Receiving Stations (GRS) located at selected sites within or near the continental United States. The ground receiving sites then convert the received energy to a form compatible with local utility power networks where the available energy will contribute to the base load power capability of the network.

All cost material on these concepts is organized by WBS element with supporting information, cost equations, technical characteristics, and results identified at the lowest possible level available from current system definitions and design concepts. Main areas of Appendix B cover:

1.1 SATELLITE SYSTEM

Elements of the satellite system are costed in this section covering hardware, software, and services applicable to the Rockwell SPS reference concept—a 3-trough/planar/klystron configuration. Basic features of Rockwell satellites are the use of gallium arsenide based solar cells subjected to various concentrations of the sun's rays to convert solar energy into its electrical equivalent. Klystron, magnetron or solid state power amplifiers are used as the means of developing high power microwave energy for transmission to earth. Characteristics of the five concepts that were costed by WBS line item are presented in Table 1.1-1.

Table 1.1-1. Satellite System Concept Summaries (June 1980)

	GaAs SOLAR CELL				GaAlAs/GaAs SOLAR CELL
	REFERENCE	DUAL END-MOUNTED	DUAL SANDWICH	MAGNETRON	DUAL SANDWICH
SATELLITE					
TYPE	PLANAR	PLANAR	COMPOUND	PLANAR	COMPOUND
CR_E	1.83	1.83	5.2	1.83	5.2
DIMENSION (METERS)	4200 × 16,000	4200 × 18,000	6600 × 28,500	4200 × 15,000	TBD
MASS ($\times 10^6$ KG)	31.63	39.97	20.53	26.80	16.39
SOLAR ARRAY/ANTENNA	DECOUPLED	DECOUPLED	SANDWICH	DECOUPLED	SANDWICH
NUMBER OF BAYS	30	36	-	30	-
SOLAR ARRAY					
NUMBER OF PANELS	60	72	-	60	-
PANEL DIMENSION (METERS)	650W×730L	650W×690L	1.83D (×2)	650W×700L	1.63D (×2)
AREA ($\times 10^6$ M^2)	28.47	32.29	5.26	27.3	4.17
GEN. POWER (GW)	9.94	11.46	4.82	9.8	6.11
ANTENNA					
TYPE	KLYSTRON	SOLID STATE	SOLID STATE	MAGNETRON	SOLID STATE
POWER OUTPUT (GW)	7.14	7.36	3.66	8.00	4.64
ILLUMINATION	10 dB GAUS.	10 dB GAUS.	UNIFORM	10 dB HANSEN	UNIFORM
APERTURE (KM)	∿1.0	1.35	1.83 (×2)	0.92	1.63 (×2)
UTILITY INTERFACE POWER (GW)	5.07	5.22	2.42	5.6	3.06
NO. OF SATELLITES ($P_T \leq 300$ GW)	60	58	125	54	98
MASS DENSITY (KG/KW_{UI})*	6.24	7.66	8.52	4.79	5.35

*KW_{UI} = KILOWATTS AT UTILITY INTERFACE NETWORK

The updated Rockwell SPS reference configuration utilizes a klystron microwave power amplifier with an end-mounted antenna to form a microwave power transmission system receiving power from a GaAs based 3-trough planar solar array (Figure 1.1-1). Solar array panels are 730 m long and 650 m wide and two of these panels make up a voltage string (43.3 kV) when using a single junction

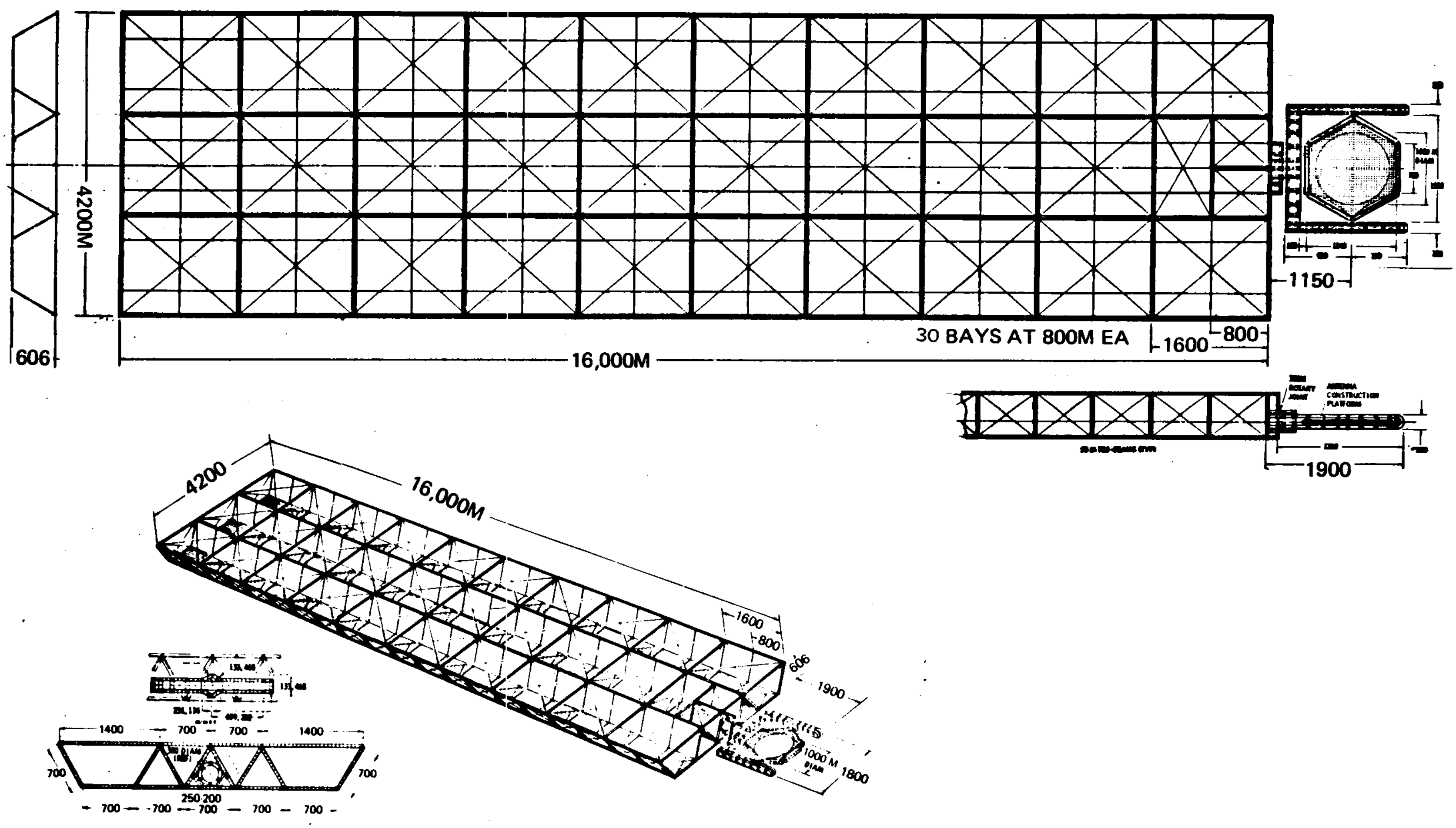


Figure 1.1-1. Rockwell SPS CR-2 Reference Configuration
(3 Trough/Planar/Klystron)—1980

GaAs cell. The 650 m width consists of 26 strips, each 25 m wide. Sizing of the array is based on a solar constant at summer solstice (1311.5 W/m^2), an end of life concentration ratio of 1.83, and an operating temperature of 113°C. The installed solar panel area is defined as 28.47×10^6 m^2 for the standard GaAs cell. Total power from the solar array output is estimated to be 9.94 GW. Total spacetenna transmitted power is 7.14 GW.

Mass properties for the 5 concepts, as well as 3 others using MBG solar cells, were identified for the systems and elements that make-up the energy conversion, power transmission, and interface segment of the satellite. These masses were then used in all cost calculations based on values (dry) without a 25% growth factor. A summary mass properties statement used in cost calculations is shown in Table 1.1-2. This mass statement is consistent with SPS concepts presented in Figure B-2.

Cost estimates for the satellite were developed in accordance with the SPS-WBS breakdown presented in Appendix A. Approximately 100 line items were analyzed within the following areas of 1.1 Satellite System definition:

SPS research and technology studies have identified the need for a demonstration article or satellite to serve as an ultimate pilot plant with possible extension into a first SPS satellite system. Cost estimates for this pilot plant and test articles have been developed and are included as Section 1.1.9—Pilot Plant/Test Article (page B-163).

Table 1.1-2. Mass Properties Summary Statement
(September 1980)

	ROCKWELL SPS CONCEPTS							
	CR = 2						CR = 5	
	UPDATED REFERENCE 3-TROUGH PLANAR/KLYSTRON ($kg \times 10^6$)		3-TROUGH/PLANAR MAGNETRON ($kg \times 10^6$)		PLANAR DUAL END MOUNTED SOLID STATE ($kg \times 10^6$)		SOLID-STATE SANDWICH DUAL ANTENNA/REFLECTOR ($kg \times 10^6$)	
	STANDARD CELL GaAs	MBG CELL GaAlAs/ GaAs	STANDARD CELL GaAs	MBG CELL GaAlAs/ GaAs	STANDARD CELL GaAs	MBG CELL GaAlAs/ GaAs	STANDARD CELL GaAs	MBG CELL GaAlAs/ GaAs
1.1.1 ENERGY CONVERSION (SOLAR ARRAY)								
STRUCTURE	1.514	1.133	1.601	1.245	1.496	1.233	3.412	2.411
PRIMARY	(0.928)	(0.804)	(0.904)	(0.565)	(1.077)	(0.902)	(3.026)	(2.138)
SECONDARY	(0.586)	(0.329)	(0.697)	(0.680)	(0.419)	(0.331)	(0.386)	(0.273)
MECHANISMS	0.070	0.070	0.070	0.070	0.087	0.078	0.027	0.019
CONCENTRATOR	1.030	0.648	0.988	0.663	1.169	0.766	2.075	1.646
SOLAR PANEL	7.174	4.804	6.880	4.619	8.138	5.607	0.076*	0.076*
POWER DISTRIBUTION AND CONTROL	2.757	1.388	4.146	2.874	1.112	0.846	0.015	0.015
POWER COND. EQUIPMENT & BATT.	(0.319)	(0.206)	(0.319)	(0.319)	(0.102)	(0.222)	(0.013)	(0.013)
POWER DISTRIBUTION	(2.438)	(1.182)	(3.827)	(2.555)	(1.010)	(0.624)	(0.002)	(0.002)
THERMAL	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE
MAINTENANCE	0.092	0.063	0.092	0.092	0.104	0.056	0.100	0.100
1.1.3 (PARTIAL) INFORMATION MANAGEMENT AND CONTROL	0.050	0.050	0.050	0.050	0.057	0.057	0.033**	0.033**
DATA PROCESSING	(0.021)	(0.021)	(0.021)	(0.021)	(0.024)	(0.024)	(0.014)	(0.014)
INSTRUMENTATION	(0.029)	(0.029)	(0.029)	(0.029)	(0.033)	(0.033)	(0.019)	(0.019)
1.1.4 (PARTIAL) ATTITUDE CONTROL	0.116	0.116	0.116	0.116	0.116	0.116	0.103	0.103
SUBTOTAL	12.803	8.272	13.943	9.729	12.279	8.759	5.841	4.403
1.1.2 POWER TRANSMISSION (ANTENNA								
STRUCTURE	0.838	0.838	0.547	0.547	1.409	1.409	0.729	0.649
PRIMARY	(0.023)	(0.023)	(0.023)	(0.023)	(0.094)	(0.094)	(0.161)	(0.143)
SECONDARY	(0.815)	(0.815)	(0.524)	(0.524)	(1.315)	(1.315)	(0.568)	(0.506)
MECHANISM	0.002	0.002	0.002	0.002	0.004	0.004	NONE	NONE
SUBARRAY	7.050	7.050	3.320	3.320	10.561	10.561	8.821	7.053
POWER DISTRIBUTION AND CONTROL	2.453	2.453	1.515	1.515	4.405	4.405	INCLUDED	INCLUDED
POWER COND. & BATT.	(1.680)	(1.680)	(0.346)	(0.346)	(2.164)	(2.164)	--	--
POWER DISTRIBUTION	(0.773)	(0.773)	(1.169)	(1.169)	(2.241)	(2.241)	--	--
THERMAL	0.720	0.720	NONE	NONE	NONE	NONE	NONE	NONE
ANTENNA CONTROL ELECTRONICS	0.170	0.170	0.170	0.170	0.340	0.340	0.340	0.340
MAINTENANCE	0.107	0.107	0.107	0.107	0.448	0.448	0.436	0.408
1.1.3 (PARTIAL) INFORMATION MANAGEMENT AND CONTROL	0.640	0.640	0.320	0.320	1.622	1.622	0.256***	0.256***
DATA PROCESSING	(0.380)	(0.380)	(0.190)	(0.190)	(1.385)	(1.385)	(0.152)	(0.152)
INSTRUMENTATION	(0.260)	(0.260)	(0.130)	(0.130)	(0.237)	(0.237)	(0.104)	(0.104)
1.1.4 (PARTIAL) ATTITUDE CONTROL	NEGLIG.	NEGLIG.	NEGLIG.	NEGLIG.	NEGLIG.	NEGLIG.	NEGLIG.	NEGLIG.
SUBTOTAL	11.980	11.980	5.981	5.981	18.789	18.789	10.582	8.706
1.1.6 INTERFACE								
STRUCTURE	0.170	0.170	0.257	0.257	0.236	0.236	N/A	N/A
PRIMARY	(0.136)	(0.136)	(0.136)	(0.136)	(0.168)	(0.168)		
SECONDARY	(0.034)	(0.034)	(0.121)	(0.121)	(0.068)	(0.068)		
MECHANISMS	0.033	0.033	0.033	0.033	0.072	0.072		
POWER DISTRIBUTION AND CONTROL	0.288	0.288	1.194	1.194	0.538	0.538		
POWER DISTRIBUTION	(0.271)	(0.271)	(1.177)	(1.177)	(0.487)	(0.487)		
SLIP RING BRUSHES	(0.017)	(0.017)	(0.017)	(0.017)	(0.051)	(0.051)		
THERMAL	NONE	NONE	NONE	NONE	NONE	NONE	N/A	N/A
MAINTENANCE	0.032	0.032	0.032	0.032	0.064	0.064	--	--
COMMUNICATION	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
SUBTOTAL	0.523	0.523	1.516	1.516	0.910	0.910	--	--
SPS TOTAL (DRY)	25.306	20.775	21.44	17.226	31.978	28.458	16.423	13.109
GROWTH (25%)	6.326	5.194	5.36	4.307	7.995	7.114	4.106	3.277
TOTAL SPS (DRY) WITH GROWTH	31.632	25.969	26.8	21.533	39.973	35.572	20.529	16.386
SATELLITE POWER AT UTILITY INTERFACE (GW)	5.07	5.07	5.6	5.6	5.22	5.22	2.41	3.06
SATELLITE DENSITY, KG/KW_{UI}	6.24	5.12	4.79	3.85	7.66	6.81	8.52	5.35

*AUXILARY POWER ONLY
**TWO-THIRDS MASS OF REFERENCE CONCEPT
***20% REFERENCE MASS PER ANTENNA

1.1.1 ENERGY CONVERSION

This element covers components required to collect solar energy, convert the solar energy to electrical energy, condition the electrical energy, and transport it to the interface subsystem (WBS No. 1.1.6).

The satellite "wing" structure, solar cells/blankets, concentrators, and power distribution/conditioning systems are included in this element plus maintenance equipment necessary to support the satellite during operational phases. The following WBS items are included in this section:

- Structure
- Concentrators
- Solar Blankets
- Power Distribution and Conditioning
- Thermal Control
- Maintenance

1.1.1.1 STRUCTURE

This element includes structural members that support concentrators, solar blankets, and other energy conversion subsystem hardware. It covers structural beams, beam couplers, cables, tensioning devices, and secondary structures required as an interface between the primary structure and the mounting attach points of components, assemblies, and subsystems.

1.1.1.1.1 Primary Structure

The satellite structure for various configurations may be considered in two broadly differing categories. The first category, applies to configurations utilizing a planar form, consists of the structure required to support the solar photovoltaic array, the rotary joint support structure, and basic antenna yoke elements. A special variant of the first category is used to establish requirements associated with the reflector/concentrator support structure. The second category is the antenna itself (WBS 1.1.2). Primary structural assemblies are made up of the tri-beam girders, tension cables, and joints. Fabrication and assembly of these structures is accomplished on orbit by beam machines and supporting auxiliary equipment (reference WBS 1.2). General configuration and design characteristics of basic tri-beam girders are illustrated in Figure 1.1-2.

Primary structural elements are made of a graphite fiber reinforced composite that must individually withstand the forces, torques, and dynamics imposed by the construction process. Once built into an assembly level, the structure must have sufficient strength and stiffness to withstand the forces of environment (gravity-gradient torques), attitude control system (forces and frequencies), and operational equipment (rotary joint microwave induced thermal environment).

The SPS requirement for low thermal distortion, under high thermal stress, dictates the need for a material with a very low coefficient of expansion. The most likely candidate, at this time, is a graphite composite material.

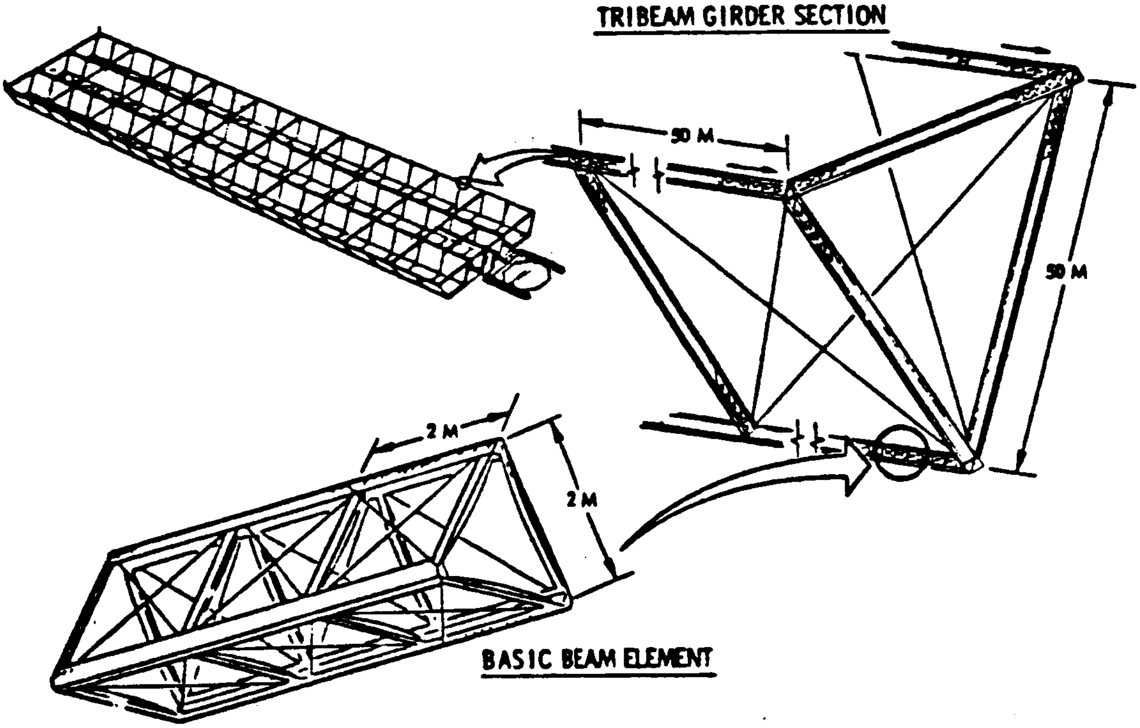


Figure 1.1-2. Primary Structure

A primary structure D&D CER was developed using graphite composite data obtained from NASA's Redstar Data Base. Tooling cost was excluded under the assumption that this cost would be incurred in the development of orbital fabrication equipment such as the beam machine. The following data points were used:

- Space Telescope Shell
- ATS-F Truss
- HEAO Optical Bench
- Shuttle Payload Bay Doors

The primary structure ICI includes the cost of raw materials only since costs associated with fabrication and assembly are costed under Space Construction and Support Equipment (WBS 1.2). The primary structure ICI cost equation is based on raw composite material stock (prepregnated graphite), where costs were obtained from vendor quotes obtained from Hercules, Fiberrite and Union Carbide.

Range of Data

D&D: 30.0 to 2000.0 kg
ICI: Unlimited

1.1.1.1.2 Secondary Structure

Secondary structure consists of passive interface attachments between primary structure and operational subsystems. Structural members are made of aluminum with the ability to articulate, rotate, or otherwise support/allow motion between the primary structure and other system elements.

This element includes all structure, consisting of mounting brackets, clamps and installation structure required as an interface and mounting attach points of components, assemblies, and subsystems. It also includes any structure required between two or more components or assemblies.

The MSFC CER was used for DDT&E and ICI costs as developed from cost data contained in the Redstar Data Base. Data from a variety of launch vehicle and unmanned satellite programs were available and the applicable data points are listed below:

S-IV Interstage	UV Instrument Mounting Assembly (ASM)
S-IC Forward Skirt	Solar Array & Boom Structure (ATS-F)
S-IC Intertank	Squib Interface Unit (ATS-F)
Solar Telescope Housing Assembly (ASM)	Interstage (Centaur)
Common Mount Assembly (ASM)	Nose Shroud (Centaur)
Telescope Gimbal Assembly (ASM)	Fixed Airlock Shroud (Skylab)
Common Mount Actuators (ASM)	Payload Shroud (Skylab)
Telescope Gimbal Actuators (ASM)	Pallet Segment (Spacelab)
Array Platform Elevation Pointing Actuator (ASM)	OSO-1
UV Gimbal Mount Actuators (ASM)	ATS-F
	S-II

Range of Data

D&D: 6.0 to 15,000.0 kg
ICI: 6.0 to 15,000.0 kg

A review of these data points indicates extrapolations at the 6 kg level were based on the ATS-F Solar Array and Boom Structure, the Squib Interface Unit, ASM Gimbal Assemblies and Actuators; where as the S-IC Intertank, Centaur Nose Shroud, and interstages were extrapolated for the 1000 kg category. The design and size of these items is considered more complex than that required for the SPS, and as a result, a complexity factor (CR) of .80 was established for the pilot plant/test article and the COTV. A CF of .70 was used for the satellite as the two prior vehicles will be completed and an improved data base will be available for the satellite secondary structure.

Tooling factors were identified by grouping secondary structure requirements for the annual production of satellites (WBS 1.1.1.1.2—Energy Conversion, WBS 1.1.2.1.2—Power Transmission, and WBS 1.1.6.1.2—Interface).

1.1.1.1.3 Mechanisms

This element covers active components such as the drives and drive motors located at the interface/energy conversion/rotary joint for yoke rotation.

Structural mechanisms consist of active subassemblies that articulate, rotate or otherwise cause or allow motion between conversion and interface elements of the satellite.

The ICI production cost CER was based on data provided by the following manufacturers:

Manufacturer	Application
Poly-Scientific	High energy
Poly-Scientific	Radar
Electro-Tec	Navy destroyer propeller system
Electro-Tec	Satellite solar array
I.E.C.	Navy shipboard hoist

Due to the difference in complexity and variations in specification requirements between ground and space qualified equipment, the following factors were applied.

Complexity Factor	× 3
Specification Uprating factor	× 3
Total	× 9

Range of Data

DDT&E: 6.0 to 15,000.0 kg
ICI: 6.0 to 15,000.0 kg

1.1.1.1.4 Cost Estimates

Table 1.1.1.1.1, 1.1.1.1.2, and 1.1.1.1.3 cover cost estimates associated with the primary and secondary structure and mechanisms of the energy conversion segment.

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.1.1.1.1   PRIMARY STRUCTURE

                       INPUT PARAMETERS                                   INPUT COEFFICIENTS

     T=       928000.000        TF=          1.000000        CDCER=            0.026910
     M=        15467.0000      O&M=          0.0             CDEXP=            0.800000
    CF=           1.000000      Z1=          1.000000        CICER=            0.000058
   PHI=           1.000000      Z2=         60.000000        CIEXP=            1.000000
     R=           0.0           Z3=         60.000000        BYEAR=                1979
    DF=           0.015000      Z4=         60.000000   Z5=          0.0            Z6=          0.0

     CALCULATED VALUES          KG          SUM TO  1.1.1.1                          $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                                    55.568

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                   0.905

  #RM =T / M                                                                  59.999

  E   =1.0 + LOG(PHI) / LOG(2.0)                                               1.000

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                       54.288

  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                  54.288

  CIPS=CTB*Z4/Z2                                                                       54.288

     CRCI   =CTB   X R                                                                  0.0
            PRE-IOC  CRCI =CRCI X Z6                                                    0.0
            POST-IOC CRCI =CRCI X (1.0-Z6)                                              0.0

     CO&M   =O&M OR CTB*Z5/Z2/ENYR                                                      0.0

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.023000    0.000050    0.0
     COMPOSITE MATERIAL. 6C BAYS - 800 M LONG X 700 M WIDE. OF CALCULATED
     IN COMBINATION WITH 1.1.2.1.1, 1.1.6.1.1,  1.1.9.1.1, 1.1.9.1.15 &
     1.1.9.1.20
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```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE    1.1.1.1.2   SECONDARY STRUCTURE

                 INPUT PARAMETERS                                       INPUT COEFFICIENTS

   T=      586000.000      TF=        0.012296          CDCER=        0.182520
   M=        5.000000     O&M=        0.0               CDEXP=        0.511000
  CF=        0.700000      Z1=        1.000000          CICER=        0.118170
 PHI=        0.980000      Z2=       60.000000          CIEXP=        0.355000
   R=        0.001111      Z3=       62.000000          BYEAR=            1979
  DF=        0.033333      Z4=       60.000000    Z5=          0.0          Z6=          0.0

  CALCULATED VALUES          KG          SUM TO   1.1.1.1                      $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                  19.906

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                 0.002

#RM =T / M                                                            117200.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                             0.971

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                    154.716


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               137.181

CIPS=CTB*Z4/Z2                                                                     137.181

   CRCI  =CTB  X R                                                                  0.152
          PRE-IOC  CRCI =CRCI X Z6                                                  0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                            0.152

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                     0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.156000    0.101000    0.0
   COMBINE SATTELLITE QUANTITIES OF 1.1.2.1.2(163000 UNITS)&
   1.1.6.1.2(6800 UNITS) FOR PHI OF & TF CALCULATIONS.
```

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE   1.1.1.1.3  MECHANISMS

                   INPUT PARAMETERS                              INPUT COEFFICIENTS

      T=      70000.0000      TF=          0.104401          CDCER=         0.182520
      M=        110.000000    U&M=         0.014999          CDEXP=         0.511000
     CF=          1.000000    Z1=          1.000000          CICER=         0.000894
    PHI=          0.980000    Z2=         60.000000          CIEXP=         0.950000
      R=          0.002222    Z3=         64.000000          BYEAR=             1979
     DF=          0.020000    Z4=         60.000000     Z5=          0.0         Z6=          0.0

     CALCULATED VALUES            KG        SUM TO  1.1.1.1                    $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                              7.396

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                            0.008

  #RM =T / M                                                           636.364

  E   =1.0 + LOG(PHI) / LOG(2.0)                                        0.971

  CIFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                 4.406


  CTB =((CLRM/E)X((#RM X     Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3             3.904

  CIPS=CTB*Z4/Z2                                                                 3.904

     CRCI  =CTB  X R                                                             0.009
            PRE-IOC  CRCI =CRCI X Z6                                             0.C
            POST-IOC CRCI =CRCI X (1.0-Z6)                                       0.009

     CO&M  =U&M OR CTB*Z5/Z2/ENYR                                                0.015

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.156000    0.000764    0.012820
     110 KG/MECHANISMS.SYSTEMS HAVE SOME DEGREE OF AUTOMATIC OR DIR. MOTION, .
     INCLUDING DRIVE MOTORS FOR ROTATION AT ROTARY JOINT (4000 KG),
     CABLE TENSION DEVICES (64800 KG), AND DOCKING PORTS (1200 KG)
```

1.1.1.2 CONCENTRATORS

This element concentrates the solar energy onto the solar blanket to increase the energy density on the conversion device. It includes the reflective material and any integral attach points required for mounting. Excluded are tools and support equipment required for deployment and tensioning.

Concentrator membranes are used to reflect the sun onto the solar cell surfaces and obtain a nominal concentration ratio of 2. The concentrator is made of (0.5-mil) aluminized Kapton. The membrane has a mass of 0.018 kg/m^2 and is mounted on the structure using attachments and tensioning devices. Excluded are tools and support equipment required for deployment.

The DDT&E CER (CD) is based on thin sheet aluminum vendor data. The ICI CER for concentrators is based on Rockwell data for Type H Kapton material with an aluminized coating. As concentrator thickness decreases, cost per unit area decreases due to diminished material requirements. At around 25 microns (1 mil), cost reductions are offset by the increased difficulty of processing thin materials after which the overall cost per unit area begins to rise. Rockwell data from Dupont indicates that the cost (1977 dollars) of 0.5 mil concentrator for the SPS would be about $4.73 per square meter. At increased demand and increased yields, cost could potentially reach $1.61 per square meter. However, the most likely value, and the value on which the concentrator ICI CER is based, was quoted at $2.58 per square meter. For the purposes of the CER, this was rounded to $3.00 ($3.51—1979 dollars) per square meter to include sensors and mounting attachments and scaled at a slope of .98 to reflect anticipated large array economies.

<u>Range of Data</u>

DDT&E: 100 m^2 - 100,000 m^2
ICI: Unlimited

Cost input parameters are shown in Table 1.1.1.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.1.2 CONCENTRATORS

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	56940000.0	TF=	1.000000			CDCER=	0.0
M=	474500.000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	1.000000			CICER=	0.000004
PHI=	0.980000	Z2=	60.000000			CIEXP=	0.950000
R=	0.001111	Z3=	62.000000			BYEAR=	1979
DF=	1.000000	Z4=	60.000000	Z5=	0.0	Z6=	0.0

CALCULATED VALUES	SQ M	SUM TO 1.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.866
#RM =T / M		120.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			93.066
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			82.586
CIPS=CTB*Z4/Z2			82.586
CRCI =CTB X R			0.092
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.092
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.0 0.000003 0.0

DENSITY = .0181 KG PER SQ METER.120 SEGMENTS

1.1.1.3 SOLAR BLANKET

This element converts solar energy to electrical energy and provides power to the power distribution and conditioning buses. It includes photovoltaic conversion cells, cover-plates, substrate, electrical interconnects, and any integral attach points required for mounting. Excluded are tools and support equipment required for deployment and tensioning.

Gallium arsenide (GaAs) cells have been selected. The cell consists of GaAs junction with a GaAlAs window, substrate, adhesive, current collectors, and an anti-reflective coating. The solar blanket consists of a Kapton membrane upon which the cells are fastened with a thermo-setting FEP adhesive. Also included in the blanket are the interconnects, thermal coating, attachments/tensioning devices, and sensors.

Historical cost data on solar arrays from previous satellite programs were readily available from the Redstar Data Base and were used to develop the CD CER.

The CD CER was based on solar array historical cost data from the following programs.

- Skylab (OWS)
- Skylab (ATM)
- FRUSA
- SEPS (Est.)

The cost of array structure and mechanisms was not included so that the data would be compatible with the SPS concept of on-orbit structure fabrication and assembly. Although there is a large difference in size between the above arrays and the SPS array, the SPS array will consist of a large number of smaller units. The development fraction (DF) was utilized to normalize the CD cost to reflect cost of only that portion of the total solar array area required to develop the power system.

Due to the rapidly changing technology, historical data is not applicable for use in estimating the SPS solar blanket production cost. The Department of Energy (DOE) has initiated the U.S. Photovoltaic Conversion Program. Two main objectives of this program are to develop by 1990 the technological and industrial capability to produce silicon solar arrays at a price of less than $500 per peak KWe and to establish by year 2000 the viability of even lower cost ($100 to $300 per KWe) and/or more efficient alternatives utilizing novel materials and devices. Since it is generally believed throughout the photovoltaic industry that low cost solar arrays are achievable and dependent on the demand for high production rates and since some progress toward meeting the DOE goal has already been made, it was decided to develop SPS solar array cost estimates on the basis of projected costs rather than historical costs.

Cost estimates for material and production processing (reference Arthur D. Little report of March 1978—Contract NAS9-15294 with NASA/JSC) were considered in the development of investment costs using the materials cost of $33/m^2$ and

a fabrication cost of $34/m^2 yielding a total of $67/m^2 (1977 dollars) for a gallium arsenide solar cell array. This assessment is also consistent with studies completed under Rockwell company sponsored activity based on 1977 prices and assuming 1990 technology.

A cost estimate was extrapolated for multi-bandgap solar cells after completing technical studies and trades of the SPS configuration. GaAlAs/GaInAs cells were researched from published literature and internal Rockwell program development expectations with tabulations as shown in Table 1.1-3 based on a solar array area of 61.2 km^2. By adding the $34/m^2 DOE goal for processing (with a complexity factor) the cost of the GaAlAs/GaInAs is projected at $76.2/m^2 (1977 dollars). These data were escalated to 1979 dollars and used in conjunction with SPS concepts requiring MBG cells.

Range of Data

DDT&E: 10-300 square meters
ICI: Unlimited

Cost estimates for GaAs solar cells used on the Rockwell reference concept are shown in Table 1.1.1.3.

Table 1.1-3. Cost Estimate of Multi-Bandgap Solar Cell

MATERIAL	AMOUNT REQUIRED (MT)	UNIT COST OF MATERIAL (Ref. 1)	TOTAL COST OF MATERIAL (*$M*)* MULTI-BANDGAP SOLAR CELLS GaAlAs/GaInAs
Gallium	780	\$200/kg	156
Arsenic	840	\$100.09/kg (\$45.4/lb) (99.999%)	84.1
Selenium	17 kg	\$192/kg (99.999%)	
Indium	26	\$96.5/kg (\$3/Troy oz.)	2.5
Silver	310	\$159.39/kg (\$72.30/lb)	49.4
Silica			
Silicon (MG)	59,311	\$1/kg	
Silicon (SEG)	13,162	\$10/kg	
Zinc	9 kg	\$1170/kg (99.999%)	
Aluminum	100 (For A),10 (For B)	\$138/kg (99.999%	14.
Gold Film + Base Metal		$\$1.82/m^2$ (Ref. 2)	115.67
Tin	880	\$12.21/kg (\$5.54/lb)	10.8
Al_2O_3 (Sapphire)	4872	\$325/kg	1,583.
Copper	860	\$1.17/kg (\$0.53/lb)	1.0
Teflon	1650	\$0.08/kg (\$0.0344/lb)	0.1
Kapton	2200	\$66.14/kg (\$30/lb) (25 μm Film)	146.
			2,162.57
		(Based on Total Array Area of 61.2 km^2)	($\$36.27/m^2$)

**Millions of dollars*

Total Array $\$/m^2$ = Materials + Processing (DOE Goal)

GaAlAs/GaInAs Array $\$/m^2 = \$35.3/m^2 + (\$34/m^2 \times 1.2) = 76.2/m^2$ (1977 Dollars) = $\$89.15/m^2$ (1979 Dollars)

REFERENCES:

(1) Evaluation of Solar Cells and Arrays for Potential Solar Power Satellite Application, ADL, March 31, 1978 (NAS9-15294).

(2) High Efficiency Thin Film GaAs Solar Cells, R. J. Stirn, JPL. April, 1976 (NSF/RA 760/28).

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.1.3 SOLAR BLANKETS

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	28470000.0	TF=	1.000000			CDCER=	0.188838
M=	18250.0000	U&M=	0.0			CDEXP=	0.394000
CF=	1.000000	Z1=	1.000000			CICER=	0.000078
PHI=	0.990000	Z2=	60.000000			CIEXP=	1.000000
R=	0.002222	Z3=	64.000000			BYEAR=	1979
DF=	0.005000	Z4=	60.000000	Z5=	0.0	Z6=	0.0

```
CALCULATED VALUES        SQ M          SUM TO  1.1.1                 $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                     20.254

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                    1.431

#RM =T / M                                                  1560.000

E    =1.0 + LOG(PHI) / LOG(2.0)                                0.986

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                      2035.508

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))      ) / Z3     1916.474

CIPS=CTB*Z4/Z2                                                      1916.473

    CRCI  =CTB  X R                                                    4.258
          PRE-IOC  CRCI =CRCI X Z6                                     0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                               4.258

    CU&M  =U&M OR CTB*Z5/Z2/ENYR                                       0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE    0.161400   0.000067   0.0
    DENSITY = 0.2525 KG PER SQ METER. 60 SECTIONS (26 PANELS EACH).
    MAJOR DDT&E COMPLETED DURING PRECURSOR ACTIVITY.
```

1.1.1.4 POWER DISTRIBUTION AND CONDITIONING (PD&C)

This element includes power feeders, switching and conditioning equipments necessary to deliver power at the required voltage and power levels throughout the satellite. An energy storage system is included, as a power source, to supply minimum power to the various subsystems during eclipse periods. Data buses are not a part of this element as they are included in the information management and control subsystem (WBS No. 1.1.3).

The PD&C system receives power from the solar photovoltaic power generation system and provides for the power conditioning and switching required to deliver the power, through its distribution network, to the satellite power transmission system. Electrical power is transferred from the solar array distribution network through a rotary joint, utilizing slip rings and brushes, to the microwave antenna distribution and conditioning system for the delivery of power at required levels. Life expectancy of the PD&C is 15 years with the exception of power conductors and slip rings which have a longer life.

1.1.1.4.1 Switch Gear and Regulators

Switch gear and regulator functions will:

- Isolate solar array blankets for maintenance work
- Provide voltage regulation of solar array output by selective switching of isolation switch gears
- Control voltage and currents through the IMCS system for short circuit protection
- Prevent large line transients
- Accommodate systematic start-up and shut-down of array during eclipse periods
- Control various loads

Primary switches will be of the Penning cross-field tube design. Functions controlled by these switches will be monitored by the IMCS to determine their status and establish the opening or closing position as required. Basically the switches are held in a closed state during the operational mode. During start-up and shut-down operations, switches will be monitored by the IMCS, and when certain voltage levels are reached, a command signal will open or close switches as needed.

1.1.1.4.2 Low Voltage Converters

Power converters and conditioners transform existing bus voltages to appropriate subsystem voltage(s) required by subsystem loads and output tolerances are based on using interface requirements. Power converters are designed for a GEO mode of operation.

1.1.1.4.3 Conductors and Insulation

Main feeders are sized to minimize combined mass of itself and the solar array mass, considering power requirements, efficiency, and the variation in resistivity with operating temperature. An average transmission efficiency of approximately 94% was used in sizing the conductor. The power distribution system utilizes flat aluminum (6101/T6) feeders where feasible, and round conductors for those subsystems where flat conductors are not feasible.

The CD CER was based on historical cost data obtained from the Redstar Data Base on the following satellite programs.

- DSCS-II
- ATS-F
- OSO-I
- ATS-B
- ATS-A
- ATS-E
- HEAO

The ICI CER was based on preprocessed aluminum material cost data and the use of 6101/T6 aluminum. Differential aluminum inflation between current prices and expected mid 1986 prices was included. Cost data was obtained from the following manufacturers:

- Reynolds Metals
- Alcoa Aluminum
- Amchem Products, Inc.
- The Yoder Company

RANGE OF DATA

DDT&E:	20 to 150 kilograms
ICI:	Unlimited

1.1.1.4.4 Slip Rings

The slip ring portion of the rotary joint is included in the PD&C of the Energy Conversion segment. Slip rings consists of an aluminum core with coin silver cladding. The core cross section is 104.9 cm^2. The slip ring diameter is 6 m with a length of 18.85 m.

Cost data for the slip rings are based upon large ground commercial and military slip rings. Since all but one of the base data slip rings were designed for ground application, it was decided that these data should not be used as a basis for estimating DDT&E costs. It was determined that the data should be used only as a basis for estimating ICI production costs and then only after applying complexity and specification uprating factors. The following factors were applied:

Complexity Factor	× 3
Specification Uprating Factor	× 3
Total	× 9

The ICI production cost CER was based on data provided by the following manufacturers:

Manufacturer	Application
Poly-Scientific	High energy
Poly-Scientific	Radar
Electro-Tec	Navy destroyer propeller system
Electro-Tec	Satellite solar array
I.E.C.	Navy shipboard hoist

Due to the relatively low production rate per year, the tooling factor is assumed to be 1.0.

The DDT&E cost was estimated with a CER developed for secondary structure which consisted of space qualified hardware of approximately the same complexity. See the discussion of the secondary structure CER.

1.1.1.4.5 Batteries

Batteries will be utilized during ecliptic periods to provide minimum energy required by energy conversion subsystems. Batteries will be of a sodium chloride design, having a density of at least 200 watt hours/kg.

DDT&E and the ICI CER's were developed using battery data from manned/ unmanned spacecraft list below:

- APOLLO Lunar Module
- APOLLO Lunar Rover
- ATS-E
- ATS-F
- HAWKEYE
- OSO-I

RANGE OF DATA

DDT&E: 1.0 to 180.0 kg
ICI: 1.0 to 180.0 kg

1.1.1.4.6 Battery PD&C

This element provides for the charging of satellite batteries and the distribution and regulation of power to and from the batteries. Included are the battery chargers, power regulators, diodes, and power conditioning equipment which directly interface with the battery subsystem. The IMS will be used to monitor and control charging elements.

The DDT&E and the ICI CER's were developed using data from the manned and unmanned spacecraft programs as noted:

- APOLLO Lunar Module
- APOLLO Lunar Rover
- ATS-E
- ATS-F
- GEMINI
- HAWKEYE
- OSI-I

RANGE OF DATA

DDT&E: 2.0 to 68.0 kg
ICI: 2.0 to 68.0 kg

1.1.1.4.7 PD&C Cost Estimates

Cost calculations developed for the energy conversion system are presented in the following tables:

Table	Description
1.1.1.4.1	Switch Gear and Regulators
1.1.1.4.2	Low-Voltage Converters
1.1.1.4.3	Conductors and Insulation
1.1.1.4.4	Slip Rings
1.1.1.4.5	Batteries
1.1.1.4.6	Battery PD&C

```
                  ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.1.1.4.1   SWITCH GEAR & REGULATORS - E.C.

                    INPUT PARAMETERS                              INPUT COEFFICIENTS

     T=     304000.000      TF=        1.000000      CDCER=          0.184860
     M=        195.000000   O&M=       0.0           CDEXP=          0.297000
    CF=          1.200000   Z1=        1.000000      CICER=          0.000468
   PHI=          0.950000   Z2=       60.000000      CIEXP=          1.000000
     R=          0.033333   Z3=      120.000000      BYEAR=              1979
    DF=          0.050000   Z4=       60.000000   Z5=         0.0    Z6=             0.0

     CALCULATED VALUES           KG          SUM TO  1.1.1.4                        $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                                      3.873

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                    0.110

  #RM =T / M                                                                          1558.974

  E    =1.0 + LOG(PHI) / LOG(2.0)                                                        0.926

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                       106.978

  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                   75.085

  CIPS=CTB*Z4/Z2                                                                        75.085

     CRCI   =CTB   X R                                                                   2.503
            PRE-IOC  CRCI =CRCI X Z6                                                     0.0
            POST-IOC CRCI =CRCI X (1.0-Z6)                                               2.503

     CO&M   =O&M OR CTB*Z5/Z2/ENYR                                                       0.0

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.158000     0.000400     0.0
     30 BAYS(60 SECTIONS) WITH 26 SETS PER SECTION OF SWITCH GEAR
     EQUIPMENT.  15 YEAR LIFE.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.1.4.2 LO-VOLTAGE CONVERTERS - E.C.

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	9000.00000	TF=	1.000000			CDCER=	0.184860
M=	5.770000	O&M=	0.0			CDEXP=	0.297000
CF=	1.200000	Z1=	1.000000			CICER=	0.000468
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.033333	Z3=	120.000000			BYEAR=	1979
DF=	0.050000	Z4=	60.000000	Z5=	0.0	Z6=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			1.362
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.003
#RM =1 / M		1559.792	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			4.202
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			3.655
CIPS=CTB*Z4/Z2			3.655
CRCI =CTB X R			0.122
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.122
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.158000 0.000400 0.0

30 BAYS (60 SECTIONS) WITH 26 SETS PER SECTION OF CONVERTER EQUIPMENT
15 YEAR LIFE.

RUCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.1.4.3 CONDUCTORS & INSULATION

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	2395000.00	TF=	1.000000			CDCER=	0.184860		
M=	1535.00000	O&M=	0.0			CDEXP=	0.297000		
CF=	1.000000	Z1=	1.000000			CICER=	0.000005		
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000		
R=	0.0	Z3=	60.000000			BYEAR=	1979		
DF=	0.100000	Z4=	60.000000	Z5=	0.0		Z6=	0.0	

CALCULATED VALUES	KG	SUM TO 1.1.1.4		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF				7.320
CLRM=CICER X (M)XX(CIEXP) X CF X TF				0.007
#RM =T / M			1560.260	
E =1.0 + LOG(PHI) / LOG(2.0)			1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))				11.209
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3				11.209
CIPS=CTB*Z4/Z2				11.209
CRC1 =CTB X R				0.0
PRE-IOC CRC1 =CRC1 X Z6				0.0
POST-IOC CRC1 =CRC1 X (1.0-Z6)				0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR				0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.158000 0.000004 0.0
30 BAYS (60 SECTIONS) WITH 26 SETS PER SECTION.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.1.4.4 SLIP RINGS

```
                 INPUT PARAMETERS                                      INPUT COEFFICIENTS

  T=       43000.0000      TF=        1.000000          CDCER=           0.182520
  M=         717.000000    O&M=       0.0               CDEXP=           0.511000
 CF=           1.500000    Z1=        1.000000          CICER=           0.000894
PHI=           0.900000    Z2=       60.000000          CIEXP=           0.950000
  R=           0.005555    Z3=       70.000000          BYEAR=               1979
 DF=           0.020000    Z4=       60.000000    Z5=        0.0            Z6=           0.0

 CALCULATED VALUES          KG          SUM TO  1.1.1.4                          $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                  8.648

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                0.692

#RM =T / M                                                                      59.972

E    =1.0 + LOG(PHI) / LOG(2.0)                                                  0.848

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                    25.999

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))            ) / Z3              13.766

CIPS=CTB*Z4/Z2                                                                    13.766

    CRCI  =CTB  X R                                                                0.076
          PRE-IOC  CRCI =CRCI X Z6                                                 0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                           0.076

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                   0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.156000    0.000764    0.0
   30 SLIP RING PAIRS (60 RINGS).
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.1.4.5 BATTERIES

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	4000.00000	TF=	0.054480			CDCER=	0.040145
M=	50.000000	O&M=	0.010850			CDEXP=	0.734000
CF=	1.200000	Z1=	1.000000			CICER=	0.030380
PHI=	0.950000	Z2=	60.000000			CIEXP=	0.241000
R=	0.033333	Z3=	120.000000			BYEAR=	1979
DF=	0.200000	Z4=	60.000000	Z5=	0.0	Z6=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			6.511
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.005
#RM =T / M	80.000		
E =1.0 + LOG(PHI) / LOG(2.0)	0.926		
CIFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.317
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.223
CIPS=CTB*Z4/Z2			0.223
CRCI =CTB X R			0.007
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.007
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.011

COMMENTS

1978 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.037000 0.028000 0.010000
50 KG PER CELL AT 10 CELLS PER BATTERY.
CF ACKNOWLEDGES SODIUM CHLORIDE VS DATA BASE. 15 YEAR LIFE. SEE ALSO
1.1.9.1.11 FOR REFERENCE TO DDT&E.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.1.4.6 BATTERY PD&C

```
                 INPUT PARAMETERS                                   INPUT COEFFICIENTS

   T=       2000.00000     TF=      0.154411          CDCER=        0.057505
   M=        250.000000    O&M=     0.0               CDEXP=        0.890000
  CF=          1.000000    Z1=      1.000000          CICER=        0.013020
 PHI=          0.950000    Z2=     60.000000          CIEXP=        0.859000
   R=          0.005555    Z3=     70.000000          BYEAR=            1979
  DF=          0.100000    Z4=     60.000000    Z5=         0.0       Z6=          0.0

  CALCULATED VALUES          KG         SUM TO  1.1.1.4                 $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                          6.421

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                        0.231

*RM =T / M                                                        8.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                    0.926

CTFU=(CLRM / E)X((*RM X Z1+.5)XX(E) -0.5XX(E))                             1.677

CTB =((CLRM/E)X((*RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3        1.247

CIPS=CTB*Z4/Z2                                                             1.247

   CRC1  =CTB  X R                                                         0.007
         PRE-IOC  CRC1 =CRC1 X Z6                                          0.0
         POST-IOC CRC1 =CRC1 X (1.0-Z6)                                    0.007

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                            0.0

COMMENTS
  1978 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.053000    0.012000    0.0
  COMBINE SATELLITE QUANTITIES FROM 1.1.2.3.6 (200 UNITS) FOR DF & TF CALCULATIONS
```

1.1.1.5 THERMAL CONTROL

This element includes any component used to modify the temperature of the energy conversion subsystem components. It includes cold plates, heat transfer and radiator devices as well as insulation, thermal control coatings and finishes. Excluded are paints or finishes applied to components during their manufacturing sequence.

1.1.1.6 MAINTENANCE

This element provides for in-place repair or replacement of components and includes work stations, tracks, access ways, and in situ repair equipment on the energy conversion segment of the satellite.

Maintenance requirements of this element are related to the satellites energy conversion section covering main structure, concentrators, solar blankets, and power distribution/conditioning equipment. Some of the items of maintenance equipment will be common-use items serving the satellite power transmission and interface segment. In these cases, the costs have been apportioned to the related WBS element. Maintenance requirements are listed in Table 1.1.1.6 and costs are presented in Tables 1.1.1.6.1, 1.1.1.6.2 and 1.1.1.6.3.

Table 1.1.1.6. Maintenance Requirements

WBS NO.	MAINTENANCE ITEM DESCRIPTION	1.1.1.6 ENERGY CONVERSION
1.1.1.6.1	"Free-Flyers" or Barge for Cargo and Personnel (Common Use Item)	0.8 Vehicle Utilization
1.1.1.6.2	Manned Manipulator Module	1 Vehicle
1.1.1.6.3	Tracks and Access Ways	84,000 kg

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.1.6.1 MAINTENANCE - FREE FLYERS

```
                    INPUT PARAMETERS                                  INPUT COEFFICIENTS

   T=      5000.00000     TF=      1.000000            CDCER=        0.0
   M=      5000.00000    O&M=      0.0                 CDEXP=        0.0
  CF=         1.250000    Z1=      0.800000            CICER=        0.006784
 PHI=         0.950000    Z2=     60.000000            CIEXP=        1.000000
   R=         0.005555    Z3=     58.000000            BYEAR=           1979
  DF=         1.000000    Z4=     48.000000     Z5=         0.0          Z6=         0.0

   CALCULATED VALUES          KG          SUM TO  1.1.1.6                    $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                               0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                            42.398

#RM =T / M                                                                1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                            0.926

CTFU=(CLRM / E)X((#RM X  Z1+.5)XX(E) -0.5XX(E))                                34.279

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3            33.758

CIPS=CTB*Z4/Z2                                                                 27.006

   CRCI  =CTB  X R                                                              0.188
          PRE-IOC  CRCI =CRCI X Z6                                              0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                        0.188

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                 0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE    0.0       0.005798    0.0
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.1.6.2 MANNED MANIPULATOR

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	3000.00000	TF=	1.000000	CDCER=	0.0
M=	3000.00000	O&M=	0.0	CDEXP=	0.0
CF=	1.100000	Z1=	1.000000	CICER=	0.006784
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.005555	Z3=	70.000000	BYEAR=	1979
DF=	1.000000	Z4=	60.000000	Z5= 0.0	Z6= 0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			22.386
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			22.467
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			17.588
CIPS=CTB*Z4/Z2			17.588
CRCI =CTB X R			0.098
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.098
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.0 0.005798 0.0

```
          ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE   1.1.1.6.3   TRACKS & ACCESS WAYS

              INPUT PARAMETERS                                    INPUT COEFFICIENTS

  T=      84000.0000     TF=        1.000000           CDCER=          0.0
  M=      84000.0000    O&M=        0.0                CDEXP=          0.0
 CF=          1.000000   Z1=        1.000000           CICER=          0.000058
PHI=          1.000000   Z2=       60.000000           CIEXP=          1.000000
  R=          0.0        Z3=       60.000000           BYEAR=              1979
 DF=          0.200000   Z4=       60.000000     Z5=          0.0          Z6=          0.0

 CALCULATED VALUES          KG          SUM TO  1.1.1.6                       $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                              4.914

#RM =T / M                                                                   1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                               1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                   4.914

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3              4.914

CIPS=CTB*Z4/Z2                                                                   4.914

    CRCI   =CTB  X R                                                             0.0
          PRE-IOC  CRCI  =CRCI X Z6                                              0.0
          POST-IOC CRCI  =CRCI X (1.0-Z6)                                        0.0

    CO&M   =O&M OR CTB*Z5/Z2/ENYR                                                0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0       0.000050     0.0
```

1.1.2 MW POWER TRANSMISSION

The MW power transmission system receives dc electrical power from the solar array via the interface subsystem. This power is conditioned, converted to microwave energy, and radiated to the ground receiving station. It includes power distribution and conditioning components, dc-to-RF conversion devices, and antenna radiating elements.

Costs in this section cover those of the Rockwell SPS reference antenna structure and subarrays with their klystrons; the power distribution and conditioning system, thermal control, phase reference system, and maintenance requirements. The MW antenna system is illustrated in Figure 1.1-3 and illustrates the basic configuration, including overall dimensions of the selected antenna structural concept.

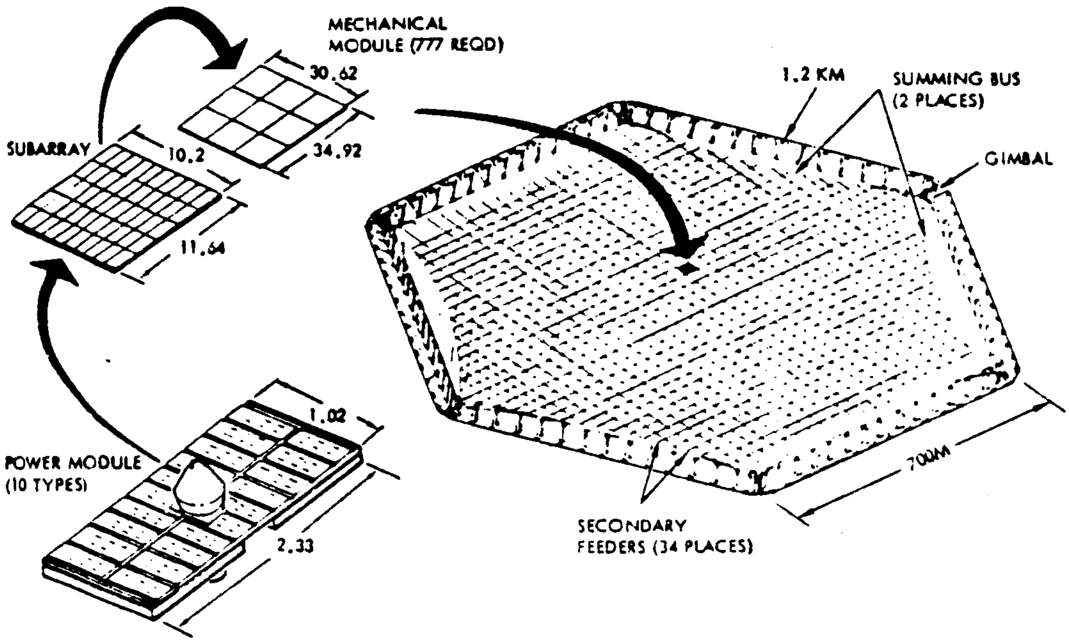


Figure 1.1-3. Microwave Transmission System
—Satellite Antenna

The smallest antenna building block is the power module, which varies in size from the one illustrated (which is used at the center portion of the antenna) to 3.40 by 5.82 meters at the periphery of the antenna. Ten different power module sizes are used to comprise the antenna element. Each power module has a klystron located in its center. The power modules are arranged into subarrays measuring 10.2 by 11.64 meters. Each subarray has its own phase control electronics. Nine subarrays are connected to form a mechanical module 30.82 by 34.92 meters. The tension web antenna is nominally 1200 m in diameter with a 1-km-diameter aperture or active area. The power modules with high power klystrons are mounted on the array structure. The klystrons serve as microwave power amplifiers that beam the MW energy to earth. Table 1.1-5

presents a summary of MPTS and satellite antenna point design characteristics. The basis for this antenna analysis was a transmission capability of 7.14 GW. An assessed maximum klystron output of 52 kW (each) was established.

Table 1.1-5. Point Design Microwave Power Transmission System (MPTS) Satellite Antenna Characteristics

MPTS System (Gaussian Beam)	
Frequency (GHz)	2.45
Maximum satellite array power density (kw/m^2)	21
Power density at ionosphere (mW/cm^2)	23
MPTS efficiency (includes ionosphere and atmospherics), %	59.3
DC input power to MPTS from solar array (GW)	9.94
DC output power to utility (GW)	5.07
Satellite MPTS Antenna Array	
Size (transmitting diameter), km	1
- Area (km^2)	0.785
Weight (kg)	11.98×10^6
Number of mechanical modules	777
Number of subarrays	6993
Number of klystron power modules	142,902

1.1.2.1 STRUCTURE

This element includes all members necessary to support transmitter subarrays and other power transmission subsystem hardware. It includes structural beams, beam couplers, cables, tensioning devices, secondary structures, and mechanisms. Microwave controlled segments or subarrays are mounted on the hexagonal tension web/compression frame configuration depicted in Figure 1.1-4.

The tension-web/compression-frame antenna structure concept consists of three major elements: (1) the tension web to which dc-to-RF conversion and transmission hardware is attached, (2) a catenary rope system which is attached to the perimeter of the tension web, and (3) a hexagonal compression frame. The tension web resists lateral pressure loading that is transmitted to the vertices of the hexagonal compression frame via the catenary rope system. These frame members are loaded in pure compression and can be analysed as columns. Three of the six catenary-to-compression-frame vertex attachments are fixed. The other three attachments at every other intersection have lateral adjustment jacks. The three fixed attachments describe a plane perpendicular to the desired boresight and the adjustable attachments maintain the tension web as a flat surface. All six catenary rope/compression frame attachments have in-plane tensioning devices that maintain the tension web flat within the design limits. Antenna elevation (north-south) adjustments are accomplished by gimbals in the trunnion structure which attach the antenna to the rotary joint. Azimuth adjustments are made by the rotary joint.

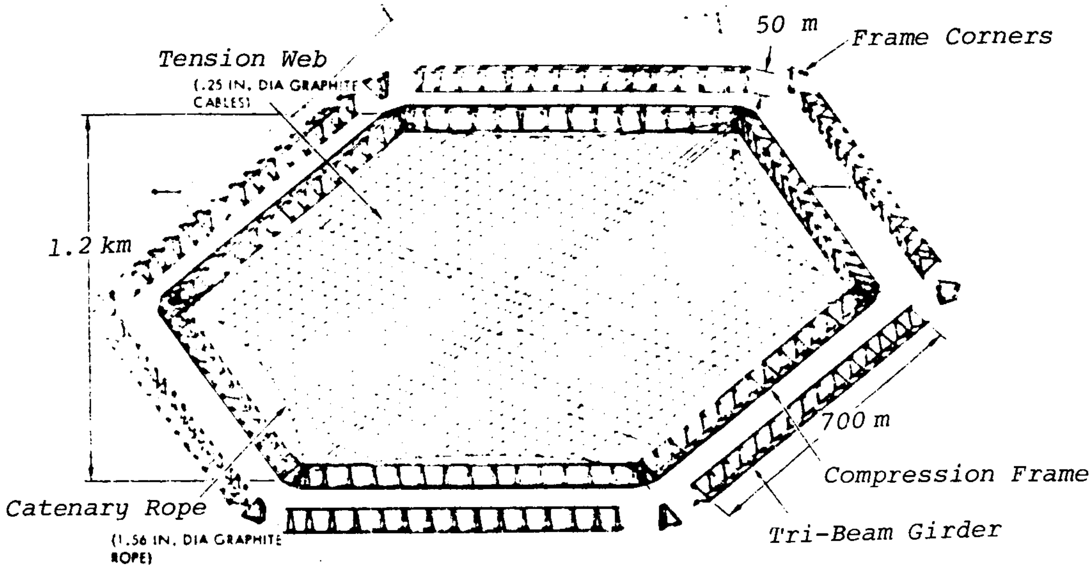


Figure 1.1-4. Microwave Antenna Structure Selected Design Concept

1.1.2.1.1 Primary Structure

This element consists of the basic supporting framework of the microwave antenna power transmission system up to the interface connection trunnion that has three main components—a tension web made from composite wires or tapes; a catenary cable that transfers the web tension to the vertices; and the octogonal compression frame. The antenna frame provides a structural support but does not include the waveguides or radio frequency assemblies associated with the microwave subsystem.

This element is limited to primary load carrying structure and does not include other secondary structure such as equipment mounts, platforms, and space equipment supports.

The SPS requirement for low thermal distortion, under high thermal stress, dictates the need for a material with a very low coefficient of expansion. The most likely candidate, at this time, is a graphite composite material.

The antenna structure D&D CER was developed using graphite composite data obtained from NASA's Redstar Data Base. Tooling cost was excluded under the assumption that this cost would be incurred in the development of orbital fabrication equipment. The following data points were used:

- Space telescope shell
- ATS-F truss
- HEAO optical bench
- Shuttle payload bay doors

The antenna structure ICI considers the cost of raw materials only since the costs associated with fabrication and assembly are charged against orbital assembly and support equipment (WBS 1.2). The antenna structure ICI cost equation is based on raw composite material stock (prepregnated graphite) cost. These material costs are based on vendor quotes obtained from Hercules, Fiberrite, and Union Carbide.

Range of Data:

D&D: 30.0 to 2000.0 kg
ICI: Unlimited

1.1.2.1.2 Secondary Structure

Secondary structure consists of passive interface attachments between primary structure and operational subsystems. Structural members are made of aluminum with the ability to articulate, rotate, or otherwise support/allow motion between the primary structure and other system elements.

This element includes all structure, consisting of mounting brackets, clamps and installation structure required as an interface and mounting attach points of components, assemblies, and subsystems. It also includes any structure required between two or more components or assemblies.

The MSFC CER was used for DDT&E and ICI cost estimates based on cost data contained in the Redstar Data Base. Data from a variety of launch vehicle and unmanned satellite programs were available and the applicable data points are listed below.

- S-IVB interstage
- S-IC forward skirt
- S-IC innertank
- Solar telescope housing assembly (ASM)
- Common mount assembly (ASM)
- Telescope gimbal assembly (ASM)
- Common mount actuators (ASM)
- Array platform elevation pointing actuator (ASM)
- UV gimbal mount actuators (ASM)
- UV instrument mount assembly (ASM)
- Solar array and boom structure (ATS-F)
- Squib interface unit (ATS-F)
- Interstage (Centaur)
- Fixed airlock shroud (Skylab)
- Payload shroud (Skylab)
- Pallet segment (Spacelab
- OSO-1
- ATS-F

S-II

Range of Data:

D&D: 6.0 to 15,000.0 kg
ICI: 6.0 to 15,000.0 kg

A review of these data points indicates extrapolations at the 6-kg level were based on the ATS-F solar array and boom structure, the squib interface unit, ASM gimbal assemblies and actuators; whereas the S-IC innertank, Centaur nose shroud, and interstages were extrapolated for the 10,000 kg category. The design and size of these items are considered more complex than that required for the SPS and as a result, a complexity factor (CF) of 0.80 was established for the pilot plant/test article and the COTV. A CF of 0.70 was used for the satellite as the two prior vehicles will be completed and an improved data base will be available for the satellite secondary structure.

Tooling factors were identified by grouping secondary structure requirements for the annual production of satellites (WBS 1.1.1.1.2, Energy Conversion; WBS 1.1.2.1.2, Power Transmission; and WBS 1.1.6.1.2, Interface).

1.1.2.1.3 Mechanisms

This element includes passive components and systems required to support rotation or elevation of the power transmission (antenna) system. Included are bearings and gearing that allow motion of the antenna gimbal to a proper orientation/position.

Operationally, attitude determination system sensors feed signals to the IMS for processing and calculation of pointing commands and the activation of drive motors.

The ICI production cost CER was based on data provided by the following manufacturers:

Manufacturer	Application
Poly-Scientific	High energy
Poly-Scientific	Radar
Electro-Tec	Navy destroyer propeller system
Electro-Tec	Satellite solar array
I.E.C.	Navy shipboard hoist

Due to differences in complexity and variations in specification requirements between ground and space-qualified equipment, the following factors were applied:

Complexity factor	× 3
Specification uprating factor	× 3
Total	× 9

Range of Data:

DDT&E: 6.0 to 15,000.0 kg
ICI: 6.0 to 15,000.0 kg

1.1.2.1.4 Cost Estimates

Input parameters T (total) and M (module) are in kilograms of mass. For cost estimates, refer to Tables 1.1.2.1.1, 1.1.2.1.2, and 1.1.2.1.3.

```
            ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE   1.1.2.1.1  PRIMARY STRUCTURE

              INPUT PARAMETERS                              INPUT COEFFICIENTS

   T=      23000.0000      TF=        1.000000      CDCER=          0.026910
   M=       3834.00000     U&M=       0.0           CDEXP=          0.800000
  CF=          1.000000    Z1=        1.000000      CICER=          0.000058
 PHI=          1.000000    Z2=       60.000000      CIEXP=          1.000000
   R=          0.0         Z3=       60.000000      BYEAR=              1979
  DF=          0.020000    Z4=       60.000000   Z5=       0.0         Z6=          0.0

   CALCULATED VALUES       KG        SUM TO  1.1.2.1                    $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                          3.632

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                        0.224

#RM =T / M                                                           5.999

E   =1.0 + LOG(PHI) / LOG(2.0)                                       1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                             1.345


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))       ) / Z3          1.345

CIPS=CTB*Z4/Z2                                                             1.345

    CRCI  =CTB  X R                                                        0.0
          PRE-IOC  CRCI =CRCI X Z6                                         0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                   0.0

    CO&M  =O&M OR CTH*Z5/Z2/ENYR                                           0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.023000    0.000050    0.0
    HEXAGON STRUCTURE, TENSION WEB DESIGN. DF CALCULATED INCOMBINATION
    WITH 1.1.1.1.1, 1.1.6.1.1, & 1.1.9.1.1, 1.1.9.1.15 & 1.1.9.1.20
```

```
                  ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
    TABLE    1.1.2.1.2   SECONDARY STRUCTURE

                    INPUT PARAMETERS                                      INPUT COEFFICIENTS

     T=        815000.000        TF=          0.012296            CDCER=          0.182520
     M=             5.000000    O&M=          0.0                 CDEXP=          0.511000
    CF=             0.700000     Z1=          1.000000            CICER=          0.118170
   PHI=             0.980000     Z2=         60.000000            CIEXP=          0.355000
     R=             0.001111     Z3=         62.000000            BYEAR=             1979
    DF=             0.033333     Z4=         60.000000      Z5=           0.0          Z6=          0.0

    CALCULATED VALUES             KG          SUM TO  1.1.2.1                             $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                                          23.561

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                         0.002

 #RM =T / M                                                                      163000.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                                        0.971

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                            213.118

 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                     188.962

 CIPS=CTB*Z4/Z2                                                                            188.962

    CRC1   =CTB   X R                                                                      0.210
           PRE-IOC   CRC1 =CRC1 X Z6                                                       0.0
           POST-IOC CRC1  =CRC1 X (1.0-Z6)                                                 0.210

    CO&M   =O&M OR CTB*Z5/Z2/ENYR                                                          0.0

 COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.156000     0.101000    0.0
    COMBINE SATELLITE QUANTITIES FROM 1.1.1.1.2(117200 UNITS)&
    1.1.6.1.2(6800 UNITS) FOR PHI, DF & TF CALCULATIONS.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.2.1.3 MECHANISMS (TRUNNIONS)

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	2000.00000	TF=	1.000000			CDCER=	0.182520		
M=	1000.00000	O&M=	0.014999			CDEXP=	0.511000		
CF=	1.000000	Z1=	1.000000			CICER=	0.000894		
PHI=	1.000000	Z2=	60.000000			CIEXP=	0.950000		
R=	0.002222	Z3=	64.000000			BYEAR=	1979		
DF=	1.000000	Z4=	60.000000	Z5=	0.0			Z6=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			8.874
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.633
#RM =T / M		2.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.266
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			1.266
CIPS=CTB*Z4/Z2			1.266
CRCI =CTB X R			0.003
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.003
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.015

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.156000 0.000764 0.012820

PASSIVE MECHANISMS LOCATED ON ANTENNA - GEAR RING AND BEARINGS.

1.1.2.2 TRANSMITTER SUBARRAYS

This element includes all hardware required for generation, distribution, phase control, and radiation of microwave energy. Systems and components are identified as subarray structure, waveguides, power amplifiers, control devices, and power harnesses. Also included are thermal control devices and finishes manufactured as an integral part of the subarray.

Reference SPS Klystron Concept

RF generators convert direct current (dc) electric power to RF microwave power. Klystrons are used in this system as a high-power RF transmitting device. Waveguides receive the RF power from the generator and radiate it to the ground-based rectenna.

Klystrons with an efficiency of 85.86% are suggested for the Rockwell reference concept microwave power transmitting antenna. The reference klystron is based on the performance of various VKS-773, 50-kW, 2.45-GHz klystrons previously built which obtained an efficiency of 74.4% without a depressed collector. Addition of a depressed collector with 55% beam power recovery efficiency plus other minor design changes will lead to an 80% efficiency. Taking into account cathode heater and solenoid power, a final efficiency of 85% was projected as technologically feasible for the year 1990 and is used in point-design calculations.

Historical cost data for some 20 phased array radars spanning over a period of the last 20 years were extracted from the Redstar Data Base and/or obtained from various contractors. The data were analyzed, normalized, and the costs were adjusted to reflect 1979 dollars. In addition, for all costs utilized, the facility receiver subsystem hardware, data subsystem costs, and basic facility/housing costs were removed.

The application of phased-array radar costs to the development cost estimates of microwave antennas was pertinent since the design and development of these physically large ground installations were conducted in much the same manner as that being utilized for the SPS. Ground array radiating elements were assembled in subarray panels, complete with radiating elements, waveguide, and cabling. Subarrays were then mounted into the facility framework, subarray cabling, and plumbing connection completed at system level, and confidence testing conducted. The same general assembly philosophy is expected to be followed for the SPS microwave antenna, the difference being that the microwave antenna will be totally assembled in the space environment.

The D&D CER was based on data from four DOD classified projects identified only as Projects 21, 22, 23, and 24, as well as the Cobra Dane, AN/SPS-48 and SAM-D (PATRIOT) radar systems.

A different approach was taken to develop TFU CERs. After reviewing the various radar systems' cost it was determined that not enough insight was afforded into the components; therefore, a "grass roots" approach was undertaken.

The microwave power transmission (MWPTS) array for the updated Rockwell reference configuration was analyzed to current design requirements and to reflect 1979 cost projections using the Exhibit C data base. The tension-web antenna is 830,264 m^2 and required 142,902 power modules with one 52-kW klystron per (LRU) module of 5.8 m^2 each.

Cost estimates were developed after careful review of MWPTS array subsystems using the MSFC data base, vendor estimates, and cost projections of equipment with similar design characteristics. A 50% allowance was provided for system integration. MPTS instrumentation requirements for voltage control measurements are included as part of Information Management and Control (WBS 1.1.3).

An analysis of klystron microwave system components is summarized in Table 1.1-6. The microwave radiating element (waveguide) is used in conjunction with microwave power generation devices (klystron or magnetron) to radiate this form of energy from a satellite located in GEO to a ground receiving station. A special study was completed to identify possible techniques of manufacturing large quantities of these elements and to project costs for their mass production.

Table 1.1-6. Detail of Rockwell Microwave System Design

MW System Component	LRU Cost (1979 Dollars)	WBS Reference
• Waveguide	348	1.1.2.2.2
• Heat pipes (thermal)	3,006	1.1.2.2.3
• Klystron (1 unit/LRU)	2,340	1.1.2.2.4
• Phase shifters	1,170	1.1.2.2.5
• Phase control electronics	955	1.1.2.2.6
• Power dividers and combiners	152	1.1.2.2.7
	7,971	
• Integration @ 50%	3,986	1.1.2.2.8
LRU cost	11,957	
LRU's/Antenna	142,902	
Total estimate/antenna	$\$1709\times10^6$	
• LRU 5.8 m^2		
• Antenna 830,264 m^2		
• Power modules 142,902 m^2		

Techniques considered by Rockwell's Advanced Manufacturing Technology group included dip brazing, fluxless brazing, and adhesive bonding. Although methods of adhesive bonding seem reasonable, it appeared that this technology would need considerable development to meet the 1990 ground rule for availability. The fluxless brazing technique appears as a practical alternative at

this time. A NASA/Langley Research Center contract (NAS1-13382) with Rockwell resulted in the fabrication of an actively cooled panel using this technique, and Rockwell has approximately 15 years of prior experience with this method Mass production requirements would dictate the use of vacuum furnaces, self-jigging features to hold components, fully automated operation with inspection on a statistical basis, special tooling, and a continuous operation.

Solid-State Array

A cost analysis of the solid-state array for the Rockwell CR-2 planar/dual-mounted antenna configuration is presented in Figure 1.1-5. Electrical power for this microwave array is received from solar panels located on the planar wing of the satellite. Amplifiers used in this configuration represent a high-cost item. System integration and test are reflected at 50% of materials and fabrication.

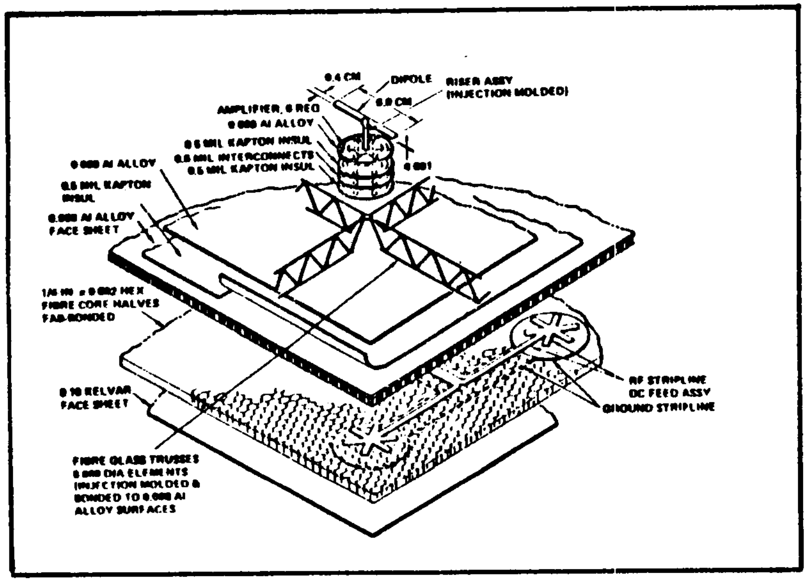
GaAs MBG Sandwich Arrays

Microwave transmission subarrays are "sandwich" designed with integral solar panels on the antennas of satellite configurations using large reflectors. Figure 1.1-6 summarizes cost estimates of this subarray, its solar panel, solid-state devices, amplifiers, and supporting components. These data were used in the costing of Rockwell SPS solid-state sandwich dual antenna/reflector concepts.

Cost Estimates

Table 1.1.2.2.1 expresses DDT&E costs based on antenna power output in kilowatts [$C_D = 0.07839\ (P_T)\ 0.507\ (CF)$]. The following tables cover other cost estimates of the klystron concept.

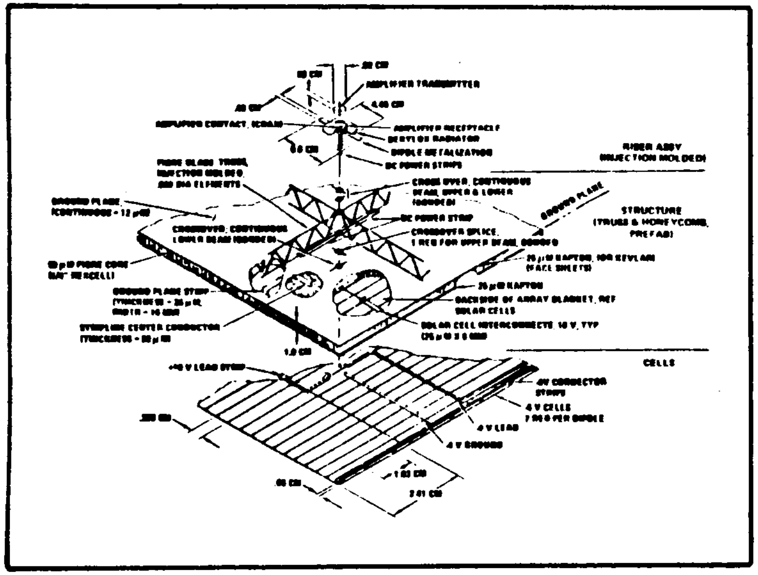
WBS Table No.	Item
1.1.2.2.2	Waveguide
1.1.2.2.3	Heat pipes—thermal
1.1.2.2.4	Klystron power module
1.1.2.2.5	Phase shifters
1.1.2.2.6	Phase control electronics
1.1.2.2.7	Power dividers and combiners
1.1.2.2.8	MW system integration



ITEM DESCRIPTION	COST/m^2 (1979 DOLLARS)
MATERIALS & FABRICATION	
STRUCTURE	
KEVLAR/HONEYCOMB	16.73
FIBERGLASS TRUSS	11.87
GROUND PLANE	
AL/KAPTON	9.28
RF STRIPLINE	3.53
AMPLIFIERS	246.00
	287.41
SYSTEM INTEGRATION & TEST (50%)	143.70
TOTAL $	431.11

SINGLE ANTENNA REQUIREMENT	
MASS PER ANTENNA	5.28×10^6 kg
APERTURE	1350 m
ANTENNA AREA	1.43×10^6 m^2
SUBARRAYS/ANTENNA	14,300
MECHANICAL MODULES	1589
DIPOLES	234×10^6
AMPLIFIERS	1407×10^6

Figure 1.1-5. Solid-State Array



ITEM DESCRIPTION	COST/m^2 (1979 DOLLARS) GaAs	MBG
MATERIALS & FAB.		
STRUCTURE		
KELVAR/HONEYCOMB	16.73	16.73
FIBERGLASS TRUSS	11.87	11.87
GROUND PLANE		
AL/KAPTON	0.58	0.58
RF STRIPLINE	3.53	3.53
BERYLLIUM OXIDE	15.21	28.36
AMPLIFIERS	41.00	82.00
SOLAR PANELS	78.00	89.15
	166.92	232.22
SYS. INTEG. & TEST (50%)	83.46	116.11
TOTAL $	250.38	348.33

SINGLE ANTENNA REQUIREMENT

ITEM	GaAs	MBG	ITEM	GaAs	MBG
MASS PER ANTENNA	4.4×10^6 kg	3.53×10^6 kg	SUBARRAYS/ANT.	26,300	20,867
APERTURE	1830 m	1630 m	MECH. MODULES	2,922	2,319
ANTENNA AREA	2.63×10^6 m^2	2.09×10^6 m^2	DIPOLES	431×10^6	342×10^6
			AMPLIFIERS	431×10^6	684×10^6

Figure 1.1-6. GaAs and MBG Sandwich Arrays

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.2.2.1 KLYSTRON MPT & RS DDT&E

```
                 INPUT PARAMETERS                                        INPUT COEFFICIENTS

  T=    7140000.00        TF=        1.000000          CDCER=           0.078390
  M=    7140000.00       O&M=        0.0               CDEXP=           0.507000
 CF=          1.250000    Z1=        1.000000          CICER=           0.0
PHI=          0.980000    Z2=       60.000000          CIEXP=           0.0
  R=          0.0         Z3=       60.000000          BYEAR=                 1979
 DF=          0.200000    Z4=       60.000000    Z5=             0.0     Z6=            0.0

  CALCULATED VALUES          KW          SUM TO  1.1.2.2                        $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                129.306

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                0.0

#RM =T / M                                                                       1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                   0.971

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                     0.0


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3                 0.0

CIPS=CTB*Z4/Z2                                                                     0.0

    CRCI  =CTB  X R                                                                0.0
          PRE-IOC  CRCI =CRCI X Z6                                                 0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                           0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                   0.0
```

COMMENTS
1979 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.078390 0.0 0.0
MSFC CER STRUCTURE. INCLUDES GROUND/SPACE EXPLORATORY DEVELOPMENT FOR ITEMS
WITHIN 1.1.2.2(TRANSMITTER SUBARRAYS), AND 1.1.2.5 (ANTENNA CONTROL),
DF CONSIDERS PRECURSOR REQUIREMENTS OF POWER TRANSMISSION & RECEPTION.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.2.2.2 WAVE GUIDE

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	142902.000	TF=	1.000000			CDCER=	0.0
M=	9.000000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	1.000000			CICER=	0.000348
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	60.000000			BYEAR=	1979
DF=	1.000000	Z4=	60.000000	Z5=	0.0	Z6=	0.0

CALCULATED VALUES PM SET SUM TO 1.1.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.003
#RM =T / M	15878.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	38.639
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	34.293
CIPS=CTB*Z4/Z2	34.293
CRC1 =CTB X R	0.0
PRE-IOC CRC1 =CRC1 X Z6	0.0
POST-IOC CRC1 =CRC1 X (1.0-Z6)	0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS
1979 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.0 0.000348 0.0
6993 SUBARRAYS IN 777 MECHANICAL MODULES. 30 YEAR LIFE. 1990 TECHNOLOGY
M CALCULATED AT 9 TYPES OF 142902 POWER MODULE WAVE GUIDES.

```
                ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE    1.1.2.2.3  HEAT PIPES -THERMAL

                INPUT PARAMETERS                                  INPUT COEFFICIENTS

   T=      142902.000      TF=          1.000000        CDCER=          0.0
   M=           9.000000   O&M=         0.0             CDEXP=          0.0
  CF=           1.000000   Z1=          1.000000        CICER=          0.003006
 PHI=           0.980000   Z2=         60.000000        CIEXP=          1.000000
   R=           0.0        Z3=         60.000000        BYEAR=              1979
  DF=           1.000000   Z4=         60.000000   Z5=          0.0     Z6=          0.0

  CALCULATED VALUES        PM SET        SUM TO  1.1.2.2                     $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                               0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                             0.027

#RM  =T / M                                                                 15878.000

E    =1.0 + LOG(PHI) / LOG(2.0)                                                 0.971

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                333.757


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3           296.216

CIPS=CTB*Z4/Z2                                                                296.216

    CRCI  =CTB   X R                                                            0.0
          PRE-IOC  CRCI =CRCI X Z6                                              0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                        0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                0.0

COMMENTS
    1979 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0         0.003006     0.0
    6993 SUBARRAYS IN 777 MECHANICAL MODULES.  30 YEAR LIFE.  1990 TECHNOLOGY
    M CALCULATED ON BASIS OF 9 TYPES OF 142902 POWER MODULE HEAT PIPES.
    HEAT PIPE MASS AT 620000 KG
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.2.2.4 KLYSTRON POWER MODULE ELEMENT

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	142902.000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.250000	Z1=	1.000000	CICER=	0.002340
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.006667	Z3=	72.000000	BYEAR=	1979
DF=	1.000000	Z4=	60.000000		
Z5=	0.0	Z6=	0.0		

CALCULATED VALUES PM SET SUM TO 1.1.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.003
#RM =T / M	142902.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	304.621
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	268.920
CIPS=CTB*Z4/Z2	268.920
CRCI =CTB X R	1.793
PRE-IOC CRCI =CRCI X Z6	0.0
POST-IOC CRCI =CRCI X (1.0-Z6)	1.793
CO&M =O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

1979 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.0 0.002340 0.0

142902 POWER MODULES IN 6993 SUBARRAYS. 1990 TECHNOLOGY.

COMPLEXITY FACTOR OF 1.25 IS USED FOR 52 KW KLYSTRON.

REPLACE CATHODES ONLY EVERY 10 YEARS AT 10% OF KLYSTRON COST ESTIMATE.

```
             ROCKWELL SPS CR-2 REFERENCE CONFIGURATION, 1980
   TABLE    1.1.2.2.5   PHASE SHIFTERS

                  INPUT PARAMETERS                                   INPUT COEFFICIENTS

    T=     142902.000      TF=        1.000000          CDCER=          0.0
    M=        20.434998   O&M=        0.0               CDEXP=          0.0
   CF=         1.250000    Z1=        1.000000          CICER=          0.001170
  PHI=         0.980000    Z2=       60.000000          CIEXP=          1.000000
    R=         0.033334    Z3=      120.000000          BYEAR=             1979
   DF=         1.000000    Z4=       60.000000     Z5=          0.0        Z6=          0.0

   CALCULATED VALUES      PM SET       SUM TO  1.1.2.2                          $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                                  0.0

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                0.030

 #RM =T / M                                                                      6993.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                                     0.971

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                   166.307


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               144.651

 CIPS=CTB*Z4/Z2                                                                   144.651

     CRCI  =CTB  X R                                                                4.822
          PRE-IOC  CRCI =CRCI X Z6                                                  0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                            4.822

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                   0.0

 COMMENTS
     1979 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0        0.001170    0.0
     6993 SUBARRAYS IN 777 MECHANICAL MODULES.  15 YEAR LIFE.  1990 TECHNOLOGY
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION, 1980

TABLE 1.1.2.2.6 PHASE CONTROL ELECTRONICS

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	142902.000	TF=	1.000000			CDCER=	0.0		
M=	183.919998	O&M=	0.0			CDEXP=	0.0		
CF=	1.250000	Z1=	1.000000			CICER=	0.000955		
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000		
R=	0.033334	Z3=	120.000000			BYEAR=	1979		
DF=	1.000000	Z4=	60.000000	Z5=	0.0			Z6=	0.0

CALCULATED VALUES PM SET SUM TO 1.1.2.2			$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.220
#RM =T / M		776.979	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			144.703
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	) / Z3		125.878
CIPS=CTB*Z4/Z2			125.878
CRCI =CTB X R			4.196
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			4.196
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1979 DATA ENTERED FOR CDCER, CICER, AND O&M WERE 0.0 0.000955 0.0

ONE PCE PER MECHANICAL MODULE.

CICER APPORTIONED PER POWER MODULE. 15 YEAR LIFE.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.2.2.7 POWER DIVIDERS & COMBINERS

```
                         INPUT PARAMETERS                                    INPUT COEFFICIENTS

   T=       142902.000       TF=          1.000000          CDCER=          0.0
   M=         183.919998     O&M=         0.0               CDEXP=          0.0
  CF=           1.250000     Z1=          1.000000          CICER=          0.000152
 PHI=           0.980000     Z2=         60.000000          CIEXP=          1.000000
   R=           0.033334     Z3=        120.000000          BYEAR=              1979
  DF=           1.000000     Z4=         60.000000    Z5=           0.0        Z6=          0.0

  CALCULATED VALUES        PM SET         SUM TO  1.1.2.2                              $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                        0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                      0.035

*RM =T / M                                                                            776.979

E    =1.0 + LOG(PHI) / LOG(2.0)                                                         0.971

CTFU=(CLRM / E)X((*RM X  Z1+.5)XX(E) -0.5XX(E))                                         23.031


CTB =((CLRM/E)X((*RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                    20.035

CIPS=CTB*Z4/Z2                                                                          20.035

    CRCI  =CTB   X R                                                                     0.668
           PRE-IOC  CRCI =CRCI X Z6                                                      0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                                0.668

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                         0.0

COMMENTS
    1979 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0          0.000152    0.0
    ONE PWR DIVIDERS & COMB PER MECHANICAL MODULE.
    CICER APPORTIONED PER POWER MODULE.  15 YEAR LIFE.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.2.2.8 MW SYSTEM INTEGRATION

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	142902.000	IF=	1.000000			CDCER=	0.0		
M=	142902.000	U&M=	0.0			CDEXP=	0.0		
CF=	1.000000	Z1=	1.000000			CICER=	0.003986		
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000		
R=	0.0	Z3=	60.000000			BYEAR=	1979		
DF=	1.000000	Z4=	60.000000	Z5=	0.0			Z6=	0.0

CALCULATED VALUES LOT SUM TO 1.1.2.2		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X IF		569.608
#RM =T / M		1.000
E =1.0 + LOG(PHI) / LOG(2.0)		1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		569.608
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	) / Z3	569.607
CIPS=CTB*Z4/Z2		569.607
CRCI =CTB X R		0.0
PRE-IOC CRCI =CRCI X Z6		0.0
POST-IOC CRCI =CRCI X (1.0-Z6)		0.0
CU&M =U&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

1979 DATA ENTERED FOR CDCER,CICER, AND U&M WERE 0.0 0.003986 0.0

SYSTEM INTEGRATION OF ITEMS 1.1.2.2.2 THROUGH 1.1.2.2.7

1.1.2.3 POWER DISTRIBUTION AND CONDITIONING (PD&C)

This element includes power feeders, switching, and conditioning equipment necessary to deliver power at the required voltage and power levels for the power transmission section (antenna portion) of the satellite. An energy storage system is included to supply power to keep the power transmission system at a ready state and for housekeeping requirements during eclipse periods. Data buses are not a part of this element as they are included in the information management and control subsystem (WBS 1.1.3).

The PD&C system receives power from the interface (energy conversion/ power transmission) system and provides for the power conditioning and switching required to deliver the power, through the distribution network, to microwave energy conversion units. On the rotating member, power is conducted through switch gears to dc/dc converters that produce six primary voltages required by the klystrons. Each voltage is then conducted to a summing bus through switch gears and power feeders and on through switch gear at mechanical modules for use at microwave subarrays to provide power for the 142,902 klystrons. A schematic of the power distribution system on the rotating antenna is shown in Figure 1.1-7 as applicable to the Rockwell reference configuration.

Batteries and battery conditioning equipment provide stored energy to power klystron heaters which keep the tubes in a ready state during eclipse periods. Batteries also provide power for necessary housekeeping activities, i.e., stationkeeping, IMCS, TT&C, etc., during these same eclipses.

The PD&C system has a life expectancy of 15 years with the exception of power conductors.

1.1.2.3.1 Switch Gear and Regulators

Switch gear and regulator functions will:

- Isolate solar array blankets for maintenance work
- Provide voltage regulation of solar array output by selective switching of isolation switch gears
- Control voltage and currents through the IMCS system for short-circuit protection
- Prevent large line transients
- Accommodate systematic startup and shutdown of array during eclipse periods
- Control various loads

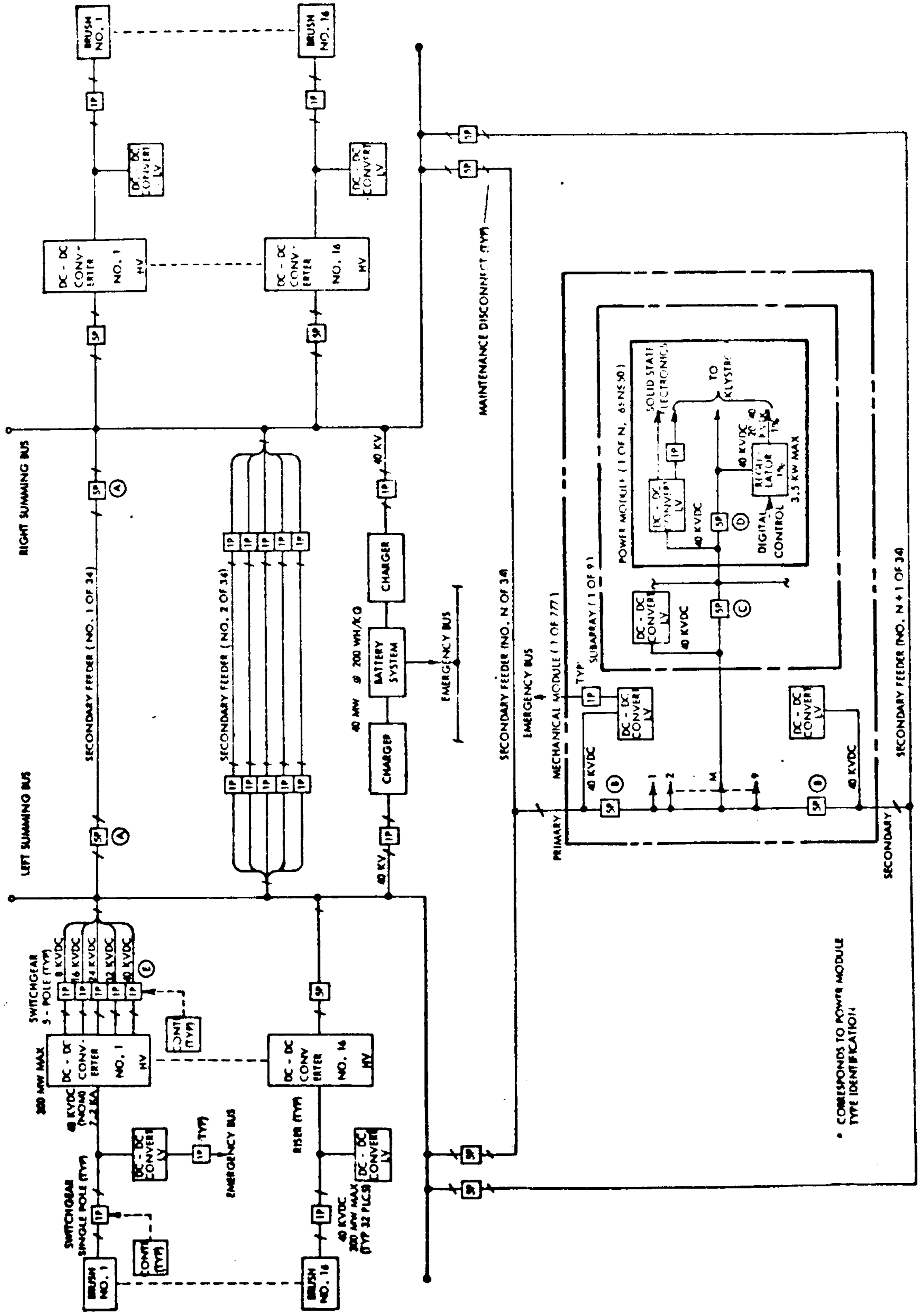


Figure 1.1-7. Microwave Antenna—Power Distribution

Primary switches will be of the Penning cross-field tube design. Functions controlled by these switches will be monitored by the IMCS to determine their status and establish the opening or closing position as required. Basically, the switches are held in a closed state during the operational mode. During start-up and shutdown operations, switches will be monitored by the IMCS and, when certain voltage levels are reached, a command signal will open or close switches as needed.

1.1.2.3.2 High-Voltage Converters

High-voltage dc-dc power converters/conditioners are used on the klystron concept to transform bus voltages from the array to a level for subsequent use by antenna subsystems.

Magnetron antenna configurations differ from the klystron version in two instances. The first is that high-voltage dc/dc converters are not needed; and second, the distribution system need accommodate only one voltage (20 kV, nominal).

1.1.2.3.3 Low-Voltage Converters

Low-voltage power converters and conditioners transform bus voltages to appropriate subsystem voltage(s) required by subsystems load, and output tolerances are based on using interface requirements. Power converters are designed for a GEO mode of operation.

1.1.2.3.4 Conductors and Insulation

Main feeders are sized to minimize the combined mass of itself and the solar array mass, considering power requirements, efficiency, and the variation in resistivity with operating temperature. An average transmission efficiency of approximately 94% was used in sizing the conductor. The power distribution system utilizes flat aluminum (6106/T6) feeders where feasible, and round conductors for those subsystems where flat conductors are not feasible.

The CD CER was based on historical cost data obtained from the Redstar Data Base on the following satellite programs:

- DSCS-II
- ATS-F
- OSO-I
- STS-B
- ATS-A
- ATS-E
- HEAO

The ICI CER was based on preprocessed aluminum material cost data and the use of 6101/T6 aluminum. Differential aluminum inflation between current prices and expected mid 1986 prices was included. Cost data were obtained from the following manufacturers:

- Reynolds Metals
- Alcoa Aluminum
- Amchem Products, Inc.
- The Yoder Company

Range of Data:

DDT&E: 20 to 150 kg
ICI: Unlimited

1.1.2.3.5 Batteries

Batteries will be utilized during the ecliptic periods to provide minimum energy to keep the klystrons warmed to a ready state and as neceesary during required housekeeping tasks. Batteries will be a sodium chloride type having the capability of providing 200 Wh/kg.

DDT&E and the ICI CERs were developed using battery data from manned/ unmanned spacecraft listed below.

- Apollo Lunar Module
- Apollo Lunar Rover
- ATS-E
- ATS-F
- Hawkeye
- OSO-I

Range of Data:

DDT&E: 1.0 to 180.0 kg
ICI: 1.0 to 180.0 kg

1.1.2.3.6 Battery PD&C

This element provides for the charging, distribution, and regulation of power to and from the batteries. Included are the battery chargers, power regulators, diodes, and power conditioning equipment which directly interface with the battery subsystem. This function will be monitored and controlled by the IMS.

DDT&E and ICI CERs were developed using data from manned and unmanned spacecraft programs as noted:

- Apollo Lunar Module
- Apollo Lunar Rover
- ATS-E
- ATS-F
- Gemini
- Hawkeye
- OSO-I

Range of Data:

DDT&E: 2.0 to 68.0 kg
ICI: 2.0 to 68.0 kg

1.1.2.3.7 PD&C Cost Estimates

Cost calculations developed for the antenna are presented in the following tables:

Table	Description	Table	Description
1.1.2.3.1	Switch gear and regulators	1.1.2.3.4	Conductors and insulation
1.1.2.3.2	High-voltage converters	1.1.2.3.5	Batteries
1.1.2.3.3	Low-voltage converters	1.1.2.3.6	Battery PD&C

```
          RUCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE    1.1.2.3.1   SWITCH GEAR & REGULATORS

              INPUT PARAMETERS                                      INPUT COEFFICIENTS

   T=     343000.000       TF=          1.000000          CDCER=           0.184860
   M=       49.000000     O&M=          0.0               CDEXP=           0.297000
  CF=        1.200000      Z1=          1.000000          CICER=           0.000468
 PHI=        0.950000      Z2=         60.000000          CIEXP=           1.000000
   R=        0.033333      Z3=        120.000000          BYEAR=              1979
  DF=        0.050000      Z4=         60.000000    Z5=          0.0          Z6=          0.0

   CALCULATED VALUES          KG         SUM TO  1.1.2.3                       $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                   4.014

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                 0.028

#RM =T / M                                                                    7000.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                   0.926

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                    108.028


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               75.807

CIPS=CTB*Z4/Z2                                                                     75.807

   CRC1  =CTB  X R                                                                  2.527
          PRE-IOC  CRC1 =CRC1 X Z6                                                  0.0
          POST-IOC CRC1 =CRC1 X (1.0-Z6)                                            2.527

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                     0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.158000    0.000400    0.0
   6993 SUBARRAYS. 343000 KG FOR 142902 SWITCHES & REGULATORS. 15 YEAR LIFE.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.2.3.2 HI-VOLTAGE CONVERTERS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1334000.00	TF=	1.000000	CDCER=	0.184860
M=	191.000000	O&M=	0.0	CDEXP=	0.297000
CF=	1.200000	Z1=	1.000000	CICER=	0.000243
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.033333	Z3=	120.000000	BYEAR=	1979
DF=	0.100000	Z4=	60.000000	Z5= 0.0	Z6= 0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			7.382
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.056
#RM =T / M		6984.293	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			310.012
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			269.643
CIPS=CTB*Z4/Z2			269.643
CRCI =CTB X R			8.988
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			8.988
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE C.158000 0.000208 0.0

6993 SUBARRAYS. 1334000 KG AT .197 KG/KW RATIO. 15 YEAR LIFE.

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.1.2.3.3  LO-VOLTAGE CONVERTERS

                    INPUT PARAMETERS                              INPUT COEFFICIENTS

     T=       3000.00000     TF=          1.000000        CDCER=          0.184860
     M=          0.400000    O&M=         0.0             CDEXP=          0.297000
    CF=          1.200000    Z1=          1.000000        CICER=          0.000468
   PHI=          0.980000    Z2=         60.000000        CIEXP=          1.000000
     R=          0.033333    Z3=        120.000000        BYEAR=             1979
    DF=          1.000000    Z4=         60.000000   Z5=         0.0         Z6=          0.0

     CALCULATED VALUES           KG         SUM TO  1.1.2.3                   $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                              2.392

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                            0.000

  #RM =T / M                                                                 7500.000

  E   =1.0 + LOG(PHI) / LOG(2.0)                                                0.971

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                 1.338


  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))           ) / Z3           1.164

  CIPS=CTB*Z4/Z2                                                                 1.164

     CRCI   =CTB  X R                                                            0.039
           PRE-IOC  CRCI =CRCI X Z6                                              0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                        0.039

     CO&M   =O&M OR CTB*Z5/Z2/ENYR                                               0.0

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.158000    0.000400    0.0
     6993 SUBARRAYS.  3000 KG AT 1 KG/KW RATIO.  15 YEAR LIFE
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.2.3.4 CONDUCTORS & INSULATION

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	773000.000	TF=	1.000000			CDCER=	0.184860		
M=	110.000000	O&M=	0.0			CDEXP=	0.297000		
CF=	1.000000	Z1=	1.000000			CICER=	0.000005		
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000		
R=	0.0	Z3=	60.000000			BYEAR=	1979		
DF=	0.100000	Z4=	60.000000	Z5=	0.0		Z6=	0.0	

CALCULATED VALUES	KG	SUM TO 1.1.2.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			5.232
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.001
#RM =T / M		7027.270	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			3.618
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			3.618
CIPS=CTB*Z4/Z2			3.618
CRCI =CTB X R			0.0
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.158000 0.000004 0.0
777 MECHANICAL MODULES, 6993 SUBARRAYS.

```
              ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
   TABLE    1.1.2.3.5   BATTERIES

                  INPUT PARAMETERS                                    INPUT COEFFICIENTS

     T=     200000.000      TF=          0.054480          CDCER=          0.0
     M=      50.000000     O&M=          0.542500          CDEXP=          0.0
    CF=       1.500000      Z1=          1.000000          CICER=          0.030380
   PHI=       0.950000      Z2=         60.000000          CIEXP=          0.241000
     R=       0.033333      Z3=        120.000000          BYEAR=             1979
    DF=       0.200000      Z4=         60.000000     Z5=          0.0        Z6=          0.0

   CALCULATED VALUES          KG          SUM TO   1.1.2.3                    $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                               0.0

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                             0.006

 #RM =T / M                                                                  4000.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                                0.926

 CIFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                 14.901


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3             10.457

 CIPS=CTB*Z4/Z2                                                                 10.457

    CRCI  =CTB  X R                                                              0.349
          PRE-IOC  CRCI =CRCI X Z6                                               0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                         0.349

    CO&M  =O&M OR CTR*Z5/Z2/ENYR                                                 0.543

 COMMENTS
    1978 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0         0.028000     0.500000
    TF & DF CALCULATED BY COMBINING QUANTITIES FROM 1.1.1.4.4 (80 CELLS)
    50 KG PER CELL AT 10 CELLS PER BETTERY.  CF ACKNOWLEDGE SODIUM CHLORINE
    TECHNOLOGY.  15 YEAR LIFE.  SEE 1.1.1.4.5 FOR DDT&E
```

RUCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.2.3.6 BATTERY P&C

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	50000.0000	TF=	0.154410			CDCER=	0.057505
M=	250.000000	O&M=	0.0			CDEXP=	0.890000
CF=	1.000000	Z1=	1.000000			CICER=	0.013020
PHI=	0.950000	Z2=	60.000000			CIEXP=	0.859000
R=	0.005555	Z3=	70.000000			BYEAR=	1979
DF=	0.005000	Z4=	60.000000	Z5=	0.0	Z6=	0.0

CALCULATED VALUES K SUM TO 1.1.2.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	7.832
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.231
#RM =T / M	200.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	33.618
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	24.587
CIPS=CTB*Z4/Z2	24.587
CRCI =CTB X R	0.137
PRE-IOC CRCI =CRCI X Z6	0.0
POST-IOC CRCI =CRCI X (1.0-Z6)	0.137
CO&M =O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS
1978 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.053000 0.012000 0.0
COMBINE SATELLITE QUANTITIES FROM 1.1.1.4.5 (8 UNITS) FOR TF&DF CALCULATIONS.

1.1.2.4 THERMAL CONTROL

This element includes any component used to modify the temperature of power transmission subsystem components. It includes coldplates, heat transfer, and radiator devices as well as insulation, thermal control coatings and finishes. Excluded are paints and finishes applied to components during their manufacturing sequence, and thermal control devices that are an integral part of another component or system.

Multi-layer insulation panels are required on back surfaces of klystron waveguides to restrict waste heat leaks which could increase temperatures of electronics to unacceptable levels. This insulation is coated externally with low absorptivity/emissivity materials to limit affect of absorbed solar flux to which the surface is exposed during part of the orbit.

CERs for insulation are based upon secondary structure CERs where the CERs were considered somewhat comparable to the requirements and application of insulation on the antenna.

Table 1.1.2.4 presents cost estimates for thermal control.

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
      TABLE    1.1.2.4     THERMAL CONTROL - INSULATION

                     INPUT PARAMETERS                                    INPUT COEFFICIENTS

      T=      100000.000       TF=        0.015694        CDCER=        0.182520
      M=           0.700000   O&M=        0.0             CDEXP=        0.511000
     CF=           1.000000    Z1=        1.000000        CICER=        0.118170
    PHI=           0.980000    Z2=       60.000000        CIEXP=        0.355000
      R=           0.0         Z3=       60.000000        BYEAR=            1979
     DF=           0.050000    Z4=       60.000000   Z5=        0.0      Z6=          0.0

      CALCULATED VALUES          KG          SUM TO  1.1.2                    $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                                14.174

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               0.002

  #RM =T / M                                                                 142857.125

  E   =1.0 + LOG(PHI) / LOG(2.0)                                                  0.971

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                  170.118


  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3            150.982

  CIPS=CTB*Z4/Z2                                                                  150.982

      CRCI   =CTB   X R                                                             0.0
             PRE-IOC  CRCI =CRCI X Z6                                               0.0
             POST-IOC CRCI =CRCI X (1.0-Z6)                                         0.0

      CO&M   =O&M OR CTB*Z5/Z2/ENYR                                                 0.0

  COMMENTS
      1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.156000    0.101000    0.0
      142902 KLYSTRON UNITS.
```

1.1.2.5 CONTROL-PHASE REFERENCE

This element comprises reference phase electronics for all subarray phase-conjugating circuits consisting of reference oscillator signal distribution and frequency conversion equipment, plus components and equipment that commonly serve all subarrays.

The transmitted signal is formed from the pilot beam by means of retro-electronics where one circuit is required per subarray. A servo system is needed to transfer the required reference phase from a central point to a mechanical module, where it is distributed to the subarrays. Main items included in this subsystem are shown in Table 1.1.2.5

Table 1.1.2.5 Control-Phase Reference

WBS NO.	ITEM/ DESCRIPTION	QUANTITY PER SATELLITE
1.1.2.5.1	REFERENCE FREQUENCY GENERATOR	1 SET (777 POWER AMPLIFIERS, 1-4 REGULATORS)
1.1.2.5.2	COAX CABLE	777 SETS
1.1.2.5.3	DEVICES FOR USE ON FREQUENCY DISTRIBUTION SYSTEM	777 SETS

Tables 1.1.2.5.1, 1.1.2.5.2, and 1.1.2.5.3 present the engineering estimates for these itesm.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.2.5.1 REFERENCE FREQUENCY GENERATOR

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	1.000000	TF=	1.000000			CDCER=	0.585000		
M=	1.000000	O&M=	0.011700			CDEXP=	1.000000		
CF=	1.000000	Z1=	1.000000			CICER=	0.117000		
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000		
R=	0.033333	Z3=	120.000000			RYEAR=	1979		
DF=	0.200000	Z4=	60.000000	Z5=	0.0			Z6=	0.0

CALCULATED VALUES SET SUM TO 1.1.2.5		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.117
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.117
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.117
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.117
CIPS=CTB*Z4/Z2		0.117
CRCI =CTB X R		0.004
PRE-IOC CRCI =CRCI X Z6		0.0
POST-IOC CRCI =CRCI X (1.0-Z6)		0.004
CO&M =O&M OR CTB*Z5/Z2/ENYR		0.012

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.500000 0.100000 0.010000

ENGINEERING ESTIMATE BASED ON DESIGN DEFINITION, 15 YEAR LIFE.

```
              ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.1.2.5.2  DIST. SYSTEM, COAXIAL CABLE

                   INPUT PARAMETERS                                INPUT COEFFICIENTS

     T=      600000.000      TF=          1.000000        CDCER=          0.000006
     M=         261.000000  O&M=          0.0             CDEXP=          1.000000
    CF=           1.000000   Z1=          1.000000        CICER=          0.000070
   PHI=           1.000000   Z2=         60.000000        CIEXP=          1.000000
     R=           0.0        Z3=         60.000000        RYEAR=              1979
    DF=           0.200000   Z4=         60.000000   Z5=          0.0       Z6=            0.0

     CALCULATED VALUES            M          SUM TO   1.1.2.5                    $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 0.702

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               0.018

  #RM =T / M                                                                    2298.850

  E   =1.0 + LOG(PHI) / LOG(2.0)                                                  1.000

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                   42.120

  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3                42.120

  CIPS=CTB*Z4/Z2                                                                   42.120

     CRCI  =CTB  X R                                                                0.0
          PRE-IOC  CRCI =CRCI X Z6                                                  0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                            0.0

     CU&M  =O&M OR CTB*Z5/Z2/ENYR                                                   0.0

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.000005   0.000060    0.0
     ESTIMATE OF 50 KG PER KM AT 30000 KG EQUALS 600 KM OF LIGHT WEIGHT,
     SHIELDED, AND RADIATION RESISTANT COAX.
```

```
                ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
      TABLE    1.1.2.5.3  DIST. SYSTEM, DEVICES

                   INPUT PARAMETERS                                  INPUT COEFFICIENTS

      T=        1554.00000     TF=          1.000000          CDCER=          0.000263
      M=           2.000000    O&M=         0.0               CDEXP=          1.000000
     CF=           1.000000    Z1=          1.000000          CICER=          0.005850
    PHI=           1.000000    Z2=         60.000000          CIEXP=          1.000000
      R=           0.033333    Z3=        120.000000          BYEAR=              1979
     DF=           0.200000    Z4=         60.000000    Z5=            0.0       Z6=          0.0

      CALCULATED VALUES         SET           SUM TO  1.1.2.5                            $,MILLIONS

   CD=CDCER X (T X DF)XX(CDEXP) X CF                                                       0.082

   CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                     0.012

   #RM =T / M                                                                    777.000

   E   =1.0 + LOG(PHI) / LOG(2.0)                                                  1.000

   CTFU=(CLRM / E)X((#RM X  Z1+.5)XX(E) -0.5XX(E))                                         9.091


   CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                     9.091

   CIPS=CTB*Z4/Z2                                                                          9.091

      CRC1  =CTB  X R                                                                      0.303
             PRE-IOC  CRC1 =CRC1 X Z6                                                      0.0
             POST-IOC CRC1 =CRC1 X (1.0-Z6)                                                0.303

      CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                         0.0

   COMMENTS
      1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.000225    0.005000    0.0
      ENGINEERING ESTIMATE.
```

1.1.2.6 MAINTENANCE

This element provides for in-place repair or replacement of components and includes work stations, tracks, access ways, and *in situ* repair equipment.

Maintenance requirements of this element are related to the power transmission (antenna) section of the satellite covering structures, subarrays (klystrons), power distribution/conditioning and energy storage, thermal control, and control elements. Some maintenance equipment is multi-purpose and, therefore, costed against applicable maintenance items on an apportioned basis.

Maintenance requirements for this element are presented in Table 1.1.2.6. Cost estimates are detailed in Tables 1.1.2.6.1, 1.1.2.6.2, 1.1.2.6.3, and 1.1.2.6.4.

Table 1.1.2.6. Maintenance Requirements

WBS NO.	MAINTENANCE ITEM DESCRIPTION	1.1.2.6 POWER TRANSMISSION
1.1.2.6.1	"FREE-FLYERS" OR BARGE FOR CARGO AND PERSONNEL (COMMON USE ITEM)	1 VEHICLE UTILIZATION
1.1.2.6.2	GANTRY CRANE AT ANTENNA	SET
1.1.2.6.3	ON-CRANE CONTROL CENTER, HOISTS, EQUIPMENT TEST GEAR, ROBOTICALS	SET
1.1.2.6.4	TRACKS AND ACCESSWAYS	12000 kg

```
                ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.1.2.6.1   MAINTENANCE - FREE FLYERS

                    INPUT PARAMETERS                              INPUT COEFFICIENTS

      T=        5000.00000     TF=          1.000000        CDCER=          0.0
      M=        5000.00000    U&M=          0.0             CDEXP=          0.0
     CF=           1.250000    Z1=          1.000000        CICER=          0.006784
    PHI=           0.950000    Z2=         60.000000        CIEXP=          1.000000
      R=           0.006666    Z3=         72.000000        BYEAR=             1979
     DF=           1.000000    Z4=         60.000000   Z5=          0.0        Z6=         0.0

     CALCULATED VALUES          KG          SUM TO  1.1.2.6                           $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                                      0.0

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                   42.398

  #RM =T / M                                                                          1.000

  E   =1.0 + LOG(PHI) / LOG(2.0)                                                      0.926

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                        42.551


  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3                    33.245

  CIPS=CTB*Z4/Z2                                                                        33.245

     CRCI  =CTB  X R                                                                     0.222
          PRE-IOC  CRCI =CRCI X Z6                                                       0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                                 0.222

     CO&M  =U&M OR CTB*Z5/Z2/ENYR                                                        0.0

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE     0.0        0.005798    0.0
```

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.1.2.6.2  GANTRY CRANE

                    INPUT PARAMETERS                                   INPUT COEFFICIENTS

       T=       40000.0000       TF=          1.000000         CDCER=          0.273780
       M=       40000.0000       O&M=         0.0              CDEXP=          0.653000
      CF=          1.100000      Z1=          1.000000         CICER=          0.000006
     PHI=          1.000000      Z2=         60.000000         CIEXP=          1.000000
       R=          0.0           Z3=         60.000000         BYEAR=             1979
      DF=          0.200000      Z4=         60.000000    Z5=          0.0      Z6=          0.0

     CALCULATED VALUES           KG           SUM TO  1.1.2.6                    $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                               106.540

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               0.257

  #RM =T / M                                                                 1.000

  E   =1.0 + LOG(PHI) / LOG(2.0)                                             1.000

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                    0.257

  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               0.257

  CIPS=CTB*Z4/Z2                                                                    0.257

     CRCI  =CTB  X R                                                               0.0
           PRE-IOC  CRCI =CRCI X Z6                                                0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                          0.0

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                  0.0

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.234000     0.000005     0.0
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.2.6.3 ON-CRANE CONTROL CENTER

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	50000.0000	TF=	1.000000			CDCER=	0.014545
M=	50000.0000	O&M=	0.0			CDEXP=	1.000000
CF=	1.000000	Z1=	0.100000			CICER=	0.006784
PHI=	0.950000	Z2=	60.000000			CIEXP=	1.000000
R=	0.000555	Z3=	7.000000			BYEAR=	1979
DF=	1.000000	Z4=	6.000000	Z5=	0.0	Z6=	0.0

CALCULATED VALUES KG SUM TO 1.1.2.6 $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	727.272
CLRM=CICER X (M)XX(CIEXP) X CF X TF	339.183
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	35.456
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	310.549
CIPS=CTB*Z4/Z2	31.055
CRCI =CTB X R	0.172
PRE-IOC CRCI =CRCI X Z6	0.0
POST-IOC CRCI =CRCI X (1.0-Z6)	0.172
CO&M =O&M OR CTF*Z5/Z2/ENYR	0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.012432 0.005798 0.0

COMMON USE EQUIPMENT. TRANSPORTABLE ITEMS AVAILABLE TO SERVICE OTHER SATELLITES

```
                  ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.1.2.6.4   TRACKS & ACCESS WAYS

                    INPUT PARAMETERS                                    INPUT COEFFICIENTS

      T=       12000.0000        TF=          1.000000          CDCER=          0.0
      M=       12000.0000       O&M=          0.0               CDEXP=          0.0
     CF=           1.000000      Z1=          1.000000          CICER=          0.000058
    PHI=           1.000000      Z2=         60.000000          CIEXP=          1.000000
      R=           0.0           Z3=         60.000000          BYEAR=              1979
     DF=           1.000000      Z4=         60.000000    Z5=         0.0           Z6=          0.0

     CALCULATED VALUES             KG          SUM TO  1.1.2.6                      $,MILLIONS

   CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 0.0

   CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               0.702

   #RM =T / M                                                                1.000

   E    =1.0 + LOG(PHI) / LOG(2.0)                                           1.000

   CTFU=(CLRM / E)X((#RM X  Z1+.5)XX(E) -0.5XX(E))                                   0.702


   CTB =((CLRM/E)X((#RM X     Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3              0.702

   CIPS=CTB*Z4/Z2                                                                    0.702

      CRCI   =CTB   X R                                                              0.0
             PRE-IOC  CRCI =CRCI X Z6                                                0.0
             POST-IOC CRCI =CRCI X (1.0-Z6)                                          0.0

      CO&M   =O&M OR CTR*Z5/Z2/ENYR                                                  0.0

   COMMENTS
      1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0        0.000050   0.0
```

1.1.3 INFORMATION MANAGEMENT AND CONTROL

This element includes those components that process information on board the satellite. This includes sensing, signal conditioning, formatting, computations, and signal routing.

The information management and control subsystem (IMCS) includes interconnecting elements between and within all satellites and ground-based operational subsystems. The IMCS also provides operational control of both the satellite and ground systems as well as providing for subsystem processing support on all but very special functions.

The satellite IMCS consists of on-board processing equipment central processing units (CPU) and memories, inter- and intra-subsystem data network (data buses), man-machine interfaces (display/control), and inter-system communication links, including RF. Items not included are those specifically provided for the control and transfer of primary power, and all elements related to system security, safety, or any other operation necessary to the continuing operation of the SPS.

Because of the early stage of program analysis, only those requirements imposed upon the IMCS by a limited number of satellite operations have been identified. These requirements generally are limited to those associated with immediate operations of an active satellite. Auxiliary functions such as ground/space communications, display/control, safety, security, etc., will be added when data become available.

The usage and application of IMCS items are identified in Table 1.1-7, and illustrate the association within subsystem functions.

Table 1.1-7. Usage/Application Matrix per Satellite

	INSTRUMENTATION		DATA ACQUISITION		DATA PROCESSING				CONTROL		
ELEMENT DESCRIPTION	SENSORS	SIGNAL CONDITIONING	SOFTWARE	SIGNAL ROUTING	SOFTWARE	FORMATTING	COMPUTATION	DISPLAY GENERATION	DISPLAYS & CONTROLS	SIGNAL CONDITIONING	WBS NO.
MASTER CONTROL COMPUTER					X	X	X	X			1.1.3.1
DISPLAYS CONTROL					X	X	X	X	X		1.1.3.2
SUPERVISORY COMPUTER					X	X	X				1.1.3.3
REMOTE COMPUTER					X	X	X				1.1.3.4
BUS CONTROL UNIT			X	X	X	X	X				1.1.3.5
MICROPROCESSORS					X	X	X				1.1.3.6
REMOTE ACQ. & CONTROL			X	X	X	X	X			X	1.1.3.7
SUB-MULTIPLEXER			X	X	X	X	X				1.1.3.8
INSTRUMENTATION	X	X									1.1.3.9
FIBER OPTICS				X							1.1.3.10
CABLES & HARNESSES	X	X	X	X	X	X	X	X	X	X	1.1.3.11

These items have been separated into general hardware groups for costing purposes.

COMPUTERS

Historical cost data were obtained for computers from the Redstar Data Base system and are listed below:

- Gemini-3
- Minuteman
- Skylab
- Viking Lander
- MOL
- HEAO

A 50% integration factor was included in the DDT&E CERs to allow for subsystem-level costs.

Range of Data:

DDT&E and ICI: 1.8 to 75.7 kg

ELECTRONIC COMPONENTS

Electronic components include submultiplexers, remote acquisition units, microprocessors, bus control units, and instrumentation.

Development of an electronic component's CER was based on selected components of the ATS-F and OSO-8 spacecraft; 19 electronic components are listed below:

ATS-F	OSO-8
Auxiliary digital sun sensors	Solar power supply
Monopulse unit	Power supply
Wideband data unit	Control decoder/demodulator
C-band data unit	Remote decoder
S/L-band transmitter	PCM decoder
VHF receiver	Format generator
Command decoder	Wheel clock
Data acquis. and control unit	Sail clock
Data switching unit	S-band transmitter
	VHF transmitter

Range of Data:

DDT&E and ICI: 1.1 to 19.6 kg

DATA BUS

This element consists of both copper wire and fiber optics. Historical cost data were obtained from the Redstar Data Base to produce a data bus DDT&E CER. Commercial prices were used for the data bus ICI CER.

Production cost information obtained from private industry for "off-the-shelf" fiber optics and copper wire are listed below.

Fiber Optics

Manufacturer	*Type*	*Characteristics*	*Cost per Meter*
ITT Electro-Optical Products Division	GG-02	Single fiber, 50 m dia.	(1-10 km) $3.25
	GS-02	Single fiber, 50 m dia.	$2.50
Valtec Fiberoptics Division	MG-05	Single fiber, 65 m dia.	$2.50
Galileo Electro-Optics Corp.	-	Single fiber, 88 m dia.	$1.58
	Average cost per meter		$2.40

One industry spokesman estimates that the cost of optical fibers would likely decrease to 40% by 1980. This study assumes a $2.40 per meter average price reduced by 40% to $1.44 per meter.

Copper Wire

Manufacturer	*Characteristics*	*Cost per Meter*
Dearborn Wire & Cable	22-gauge, stranded silver plate	$ 0.807
Standard Wire & Cable	22-gauge, stranded silver plate	$ 0.705
Karen, Inc.	22-gauge, 2-conductor silver plate	$ 0.807
Mil-Spec Wire & Cable Corporation	22-gauge, 19-30 stranded	$ 0.610
	Average cost per meter	$ 0.732

Instrumentation input parameters' T&M are in kilograms.

Cost estimates for the items of Table 1.1-7 are presented in Tables 1.1.3.1 through 1.1.3.11, inclusive.

RUCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.3.1 MASTER CONTROL COMPUTER

INPUT PARAMETERS				INPUT COEFFICIENTS			
T=	1000.00000	TF=	0.900000	CDCER=	0.740610		
M=	500.000000	O&M=	0.0	CDEXP=	0.521000		
CF=	1.000000	Z1=	1.000000	CICER=	0.201240		
PHI=	0.800000	Z2=	60.000000	CIEXP=	0.535000		
R=	0.003333	Z3=	66.000000	BYEAR=	1979		
DF=	0.500000	Z4=	60.000000	Z5=	0.0	Z6=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			18.869
CLRM=CICER X (M)XX(CIEXP) X CF X TF			5.034
#RM =T / M			2.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.678
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			9.179
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			3.021
CIPS=CTB*Z4/Z2			3.021
CRCI =CTB X R			0.010
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.010
CO&M =O&M OR CTR*Z5/Z2/ENYR			0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.633000 0.172000 0.0

REFERENCE PRECURSOR REQUIREMENTS 1.1.9.1.40

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.3.2 DISPLAYS & CONTROLS

```
                INPUT PARAMETERS                                      INPUT COEFFICIENTS

    T=        200.000000     TF=          0.900000           CDCER=          0.119340
    M=        200.000000    O&M=          0.0                CDEXP=          0.879000
   CF=          1.000000     Z1=          1.000000           CICER=          0.080730
  PHI=          0.800000     Z2=         60.000000           CIEXP=          0.557000
    R=          0.003333     Z3=         66.000000           BYEAR=             1979
   DF=          1.000000     Z4=         60.000000    Z5=          0.0          Z6=          0.0

   CALCULATED VALUES          KG          SUM TO  1.1.3                              $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                  12.572

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                 1.390

#RM =T / M                                                                    1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                0.678

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                      1.417


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                 0.515

CIPS=CTB*Z4/Z2                                                                      0.515

    CRCI  =CTB  X R                                                                 0.002
          PRE-IOC  CRCI =CRCI X Z6                                                  0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                            0.002

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                    0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.102000    0.069000    0.0
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.3.3 SUPERVISORY COMPUTER

INPUT PARAMETERS					INPUT COEFFICIENTS		
T=	84.000000	TF=	0.700000		CDCER=	0.740610	
M=	14.000000	O&M=	0.0		CDEXP=	0.521000	
CF=	1.000000	Z1=	1.000000		CICER=	0.201240	
PHI=	0.850000	Z2=	60.000000		CIEXP=	0.535000	
R=	0.003333	Z3=	66.000000		BYEAR=	1979	
DF=	0.200000	Z4=	60.000000	Z5=	0.0	Z6=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			3.221
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.578
#RM =T / M			6.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.766
CIFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			2.721
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			1.109
CIPS=CTB*Z4/Z2			1.109
CRCI =CTB X R			0.004
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.004
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.633000 0.172000 0.0

6 REQUIRED FOR RCI

```
            ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
   TABLE   1.1.3.4    REMOTE COMPUTER

               INPUT PARAMETERS                                INPUT COEFFICIENTS

     T=         518.000000    TF=        0.400000           CDCER=         0.740610
     M=          14.000000   O&M=        0.0                CDEXP=         0.521000
    CF=           1.000000    Z1=        1.000000           CICER=         0.201240
   PHI=           0.850000    Z2=       60.000000           CIEXP=         0.535000
     R=           0.003333    Z3=       66.000000           BYEAR=            1979
    DF=           0.030000    Z4=       60.000000    Z5=          0.0          Z6=          0.0

   CALCULATED VALUES          KG          SUM TO  1.1.3                       $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                               3.093

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                             0.330

 #RM =T / M                                                               37.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                            0.766

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                  6.664


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3               2.560

 CIPS=CTB*Z4/Z2                                                                  2.560

     CRCI  =CIB  X R                                                             0.009
          PRE-IOC  CRCI =CRCI X Z6                                               0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                         0.009

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                0.0

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.633000   0.172000   0.0
```

```
                  ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
 TABLE    1.1.3.5     BUS CONTROL UNIT

                  INPUT PARAMETERS                                   INPUT COEFFICIENTS

   T=        4110.00000     TF=        0.076000           CDCER=         0.119340
   M=           5.000000   O&M=        0.0                CDEXP=         0.879000
  CF=           1.000000    Z1=        1.000000           CICER=         0.080730
 PHI=           0.950000    Z2=       60.000000           CIEXP=         0.557000
   R=           0.003333    Z3=       66.000000           BYEAR=             1979
  DF=           0.012000    Z4=       60.000000   Z5=           0.0          Z6=         0.0

 CALCULATED VALUES          KG        SUM TO  1.1.3                        $,MILLIONS

CU=CDCER X (T X DF)XX(CDEXP) X CF                                              3.672

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                            0.015

#RM =T / M                                                                822.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                              0.926

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                 8.119

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3              5.958

CIPS=CTB*Z4/Z2                                                                 5.958

   CRC1  =CTB  X R                                                             0.020
         PRE-IOC  CRC1 =CRC1 X Z6                                              0.0
         POST-IOC CRC1 =CRC1 X (1.0-Z6)                                        0.020

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.102000    0.069000    0.0
   822 UNITS REQUIRED. REFR PRECURSOR REQUIREMENTS 1.1.9.1.41
```

```
                 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.1.3.6     MICROPROCESSORS

                    INPUT PARAMETERS                                    INPUT  COEFFICIENTS

      T=        3885.00000     TF=          0.078000        CDCER=          0.119340
      M=           5.000000    U&M=         0.0             CDEXP=          0.879000
     CF=           1.000000    Z1=          1.000000        CICER=          0.080730
    PHI=           0.950000    Z2=         60.000000        CIEXP=          0.557000
      R=           0.003333    Z3=         66.000000        BYEAR=             1979
     DF=           0.013000    Z4=         60.000000    Z5=           0.0       Z6=          0.0

     CALCULATED VALUES           KG          SUM TO  1.1.3                       $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 3.750

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               0.015

  #RM =T / M                                                                     777.000

  E    =1.0 + LOG(PHI) / LOG(2.0)                                                  0.926

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                    7.910


  CTB =((CLRM/E)X((#RM X     Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               5.804

  CIPS=CTB*Z4/Z2                                                                    5.804

     CRCI  =CTB  X R                                                                0.019
          PRE-IOC  CRCI =CRCI X Z6                                                  0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                            0.019

     CO&M  =U&M OR CTB*Z5/Z2/ENYR                                                   0.0

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.102000    0.069000    0.0
     777 MICRO-PROCESSORS REFR. PRECURSOR REQUIREMENTS 1.1.9.1.4.2
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.3.7 REMOTE ACQUISITION & CONTROL

INPUT PARAMETERS				INPUT COEFFICIENTS			
T=	4925.00000	TF=	0.069000	CDCER=	0.119340		
M=	5.000000	O&M=	0.0	CDEXP=	0.879000		
CF=	1.000000	Z1=	1.000000	CICER=	0.080730		
PHI=	0.950000	Z2=	60.000000	CIEXP=	0.557000		
R=	0.003333	Z3=	66.000000	BYEAR=	1979		
DF=	0.010000	Z4=	60.000000	Z5= 0.0	Z6=	0.0	

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			3.668
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.014
#RM =T / M		985.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			8.716
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			6.395
CIPS=CTB*Z4/Z2			6.395
CRCI =CTB X R			0.021
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.021
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.102000 0.069000 0.0

REFR PRECURSOR REQUIREMENT 1.1.9.1.43

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.3.8 SUBMULTIPLEXORS

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	93000.0000	TF=	0.022000			CDCER=	0.119340		
M=	3.000000	O&M=	0.0			CDEXP=	0.679000		
CF=	1.000000	Z1=	1.000000			CICER=	0.080730		
PHI=	0.960000	Z2=	60.000000			CIEXP=	0.557000		
R=	0.003333	Z3=	66.000000			BYEAR=	1979		
DF=	0.000320	Z4=	60.000000	Z5=	0.0			Z6=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			2.356
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.003
#RM =T / M		31000.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			77.359
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			68.467
CIPS=CTB*Z4/Z2			68.467
CRCI =CTB X R			0.228
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.228
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.102000 0.069000 0.0

REFR PRECURSOR REQUIREMENT 1.1.9.1.44

```
              ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
  TABLE    1.1.3.9     INSTRUMENTATION

                 INPUT PARAMETERS                                  INPUT  COEFFICIENTS

    T=     289000.000        TF=          1.000000       CDCER=          0.000117
    M=          0.074100    O&M=          0.0            CDEXP=          1.000000
   CF=          1.000000     Z1=          1.000000       CICER=          0.000468
  PHI=          0.980000     Z2=         60.000000       CIEXP=          1.000000
    R=          0.003333     Z3=         66.000000       BYEAR=              1979
   DF=          1.000000     Z4=         60.000000    Z5=         0.0        Z6=          0.0

  CALCULATED VALUES        KG          SUM TO  1.1.3                      $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                            33.813

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                           0.000

*RM =T / M                                                               3900134.00

E   =1.0 + LOG(PHI) / LOG(2.0)                                              0.971

CTFU=(CLRM / E)X((*RM X Z1+.5)XX(E) -0.5XX(E))                               89.513


CTB =((CLRM/E)X((*RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3         79.222

CIPS=CTB*Z4/Z2                                                               79.222

    CRCI  =CTB  X R                                                           0.264
          PRE-IOC  CRCI =CRCI X Z6                                            0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                      0.264

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                              0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.000100    0.000400    0.0
    M=APPROX MASS PER SENSOR.  REFR PRECURSOR REQUIREMENTS 1.1.9.1.45
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.3.10 OPTICAL FIBER

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	62.000000	TF=	1.000000			CDCER=	0.277290
M=	62.000000	U&M=	0.0			CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000			CICER=	0.011956
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.003333	Z3=	66.000000			BYEAR=	1979
DF=	1.000000	Z4=	60.000000	Z5=	0.0	Z6=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.945
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.741
*RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((*RM X Z1+.5)XX(E) -0.5XX(E))			0.742
CTB =((CLRM/E)X((*RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.675
CIPS=CTB*Z4/Z2			0.675
CRC1 =CTB X R			0.002
PRE-IOC CRCI =CRC1 X Z6			0.0
POST-IOC CRC1 =CRC1 X (1.0-Z6)			0.002
CO&M =U&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE 0.237000 0.010219 0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.3.11 CABLES/HARNESS

```
                INPUT PARAMETERS                                         INPUT COEFFICIENTS

    T=     293000.000      TF=        1.000000           CDCER=          0.277290
    M=        377.000000   U&M=       0.0                CDEXP=          0.297000
   CF=          1.000000   Z1=        1.000000           CICER=          0.000070
  PHI=          0.980000   Z2=       60.000000           CIEXP=          1.000000
    R=          0.003333   Z3=       66.000000           BYEAR=              1979
   DF=          1.000000   Z4=       60.000000     Z5=           0.0          Z6=          0.0

   CALCULATED VALUES        KG         SUM TO  1.1.3                                $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                                     11.657

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                    0.026

 #RM =T / M                                                                  777.188

 E   =1.0 + LOG(PHI) / LOG(2.0)                                                0.971

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                        17.447


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))            ) / Z3                 15.444

 CIPS=CTB*Z4/Z2                                                                        15.444

    CRCI  =CTB  X R                                                                     0.051
          PRE-IOC  CRCI =CRCI X Z6                                                      0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                                0.051

    CO&M  =U&M OR CTB*Z5/Z2/ENYR                                                        0.0

 COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.237000    0.000060    0.0
    777 MECHANICAL MODULES
```

1.1.4 ATTITUDE CONTROL AND STATIONKEEPING

This element includes components required to orient and maintain satellite position and attitude in geosynchronous orbit as shown in Figure 1.1-8. Major items include the attitude reference determination system with sensors, processors and gyros, reaction control system components and thrusters, plus power processing equipment and propellants.

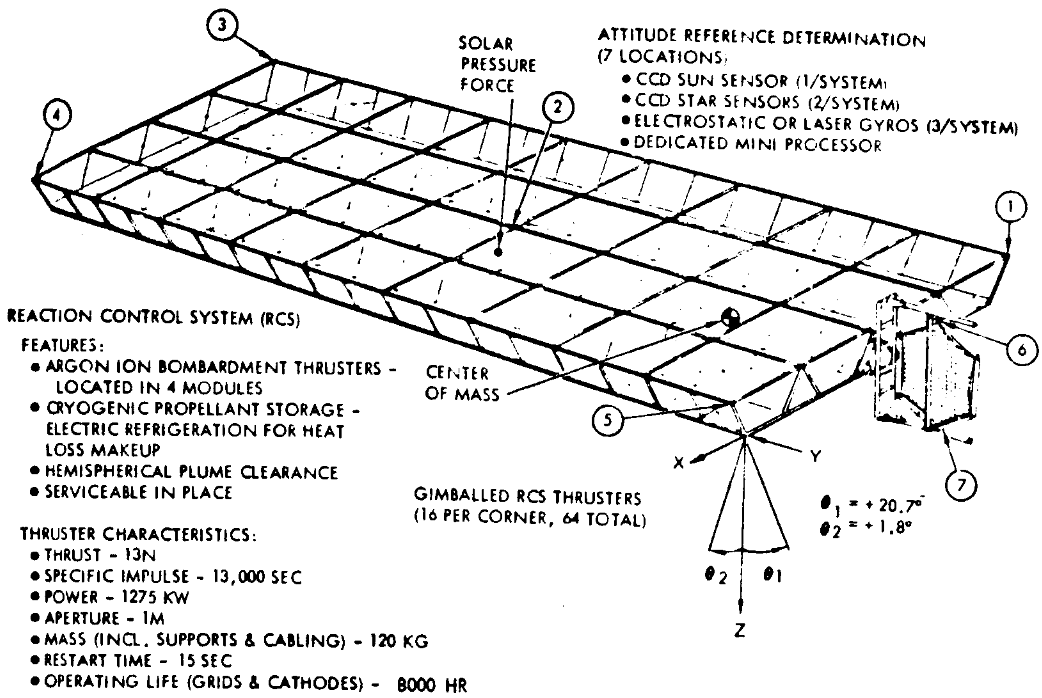


Figure 1.1-8. ACSS Equipment Locations

The baseline ACSS features an argon-ion bombardment thruster RCS whose characteristics are:

- Thrusters located in four modules at each corner of the satellite
- Each module has 16 thrusters
- Cryogenic propellant storage/electric refrigeration with heat loss makeup
- Hemispherical plume characteristics
- Serviceable in place

The system operates on an average of 36 thrusters. A total of 64 thrusters is included to provide the required redundancy. The redundancy was based on an annual maintenance/servicing interval, 5000-hour thruster grid lifetime, and five-year thruster MTBF. Sixteen thrusters are located on the lower portion of each corner of the spacecraft. Each thruster is gimbaled individually to facilitate thruster servicing, to permit operation of adjacent thrusters during

servicing, and to provide redundancy. The thrusters nominally provide a force vector approximately in the direction of the sun to counter solar pressure force (stationkeeping) which is the dominant thruster requirement. Thrusters are gimbaled through small angles (as illustrated) and differentially throttled to provide remaining forces and torques for attitude control and stationkeeping.

Sensors that make up the attitude reference determination system include:

- CCD sun sensor (one/system)
- CCD star sensors (two/system)
- Electrostatic or laser gyros (3/system)
- Dedicated mini-processor

The attitude reference determination system features charged coupled device (CCE), star and sun sensors as well as electrostatic or laser gyros and dedicated microprocessors. Seven attitude reference determination units are located at various locations on the satellite in order to sense thermal and dynamic body bending, and to desensitize the system to these disturbances. The control algorithms will feature statistical estimators for determining principal axis orientation, body bending state observers or estimators, and a quasi-linear propulsion thrust command policy to provide precise control and minimize structural bending excitation.

Mass properties of the ACSS are presented in Table 1.1-8. This summary includes the mass of individual elements with propellant weight on an annual basis per satellite.

Table 1.1-8. ACSS Mass Summary

Reference WBS No.	Item	Mass/ kg
1.1.4.1.1	Attitude Reference Determination Systems (7)	1,000
1.1.4.1.1	Thrusters—64 @ 120 kg/thruster	7,335
1.1.4.1.4	Thruster gimbals and mounting	2,000
1.1.4.1.2	Condustors/insulation	2,000
1.1.4.1.1	Tanks, lines, refrigeration	8,500
1.1.4.1.3	Power processing equipment	2,000
	Total (dry)	22,835
1.1.4.2	Argon propellant—annual requirement/satellite	85,390

Historical cost data were obtained from NASA's Redstar Data Base; however, it is limited relative to electrical propulsion. Consequently, study data were utilized where necessary. Ion bombardment thrusters are argon propellants with a low thrust but significantly higher specific impulse, thus reducing propellant resupply cost.

Development of the propulsion subsystem CERs was based on spacecraft programs listed below:

- SEPS (Boeing) Study
- SEPS (Rockwell) Study
- SERT-II
- ATS-F (Ion Experiment)
- Rockwell SPS Study
- SERT-C Study

Range of Data:

DDT&E and ICI: 18.0 to 107,500 kg

Cost estimates are identified in Tables 1.1.4.1.1, 1.1.4.1.2, 1.1.4.1.3, 1.1.4.1.4, and 1.1.4.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE 1.1.4.1.1 ACS THRUSTER COMPONENTS

```
                 INPUT PARAMETERS                                    INPUT COEFFICIENTS

   T=      16835.0000     TF=        0.300000          CDCER=          1.312739
   M=        140.000000   U&M=       0.0               CDEXP=          0.190000
  CF=          1.000000   Z1=        1.000000          CICER=          0.066690
 PHI=          0.980000   Z2=       60.000000          CIEXP=          0.729000
   R=          0.003333   Z3=       66.000000          BYEAR=              1979
  DF=          0.300000   Z4=       60.000000    Z5=          0.0         Z6=        0.0

   CALCULATED VALUES          KG           SUM TO  1.1.4.1                      $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                  6.635

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                0.734

#RM =T / M                                                                       120.250

E   =1.0 + LOG(PHI) / LOG(2.0)                                                  0.971

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                    79.004


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3              69.979

CIPS=CTB*Z4/Z2                                                                    69.979

    CRCI  =CTB  X R                                                                0.233
          PRE-IOC  CRCI =CRCI X Z6                                                 0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                           0.233

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                   0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      1.122000     0.057000    0.0
    INCLUDES 64 THRUSTERS, TANKS, PROPELLANT LINES, AND ATTITUE REFR.
    SYSTEM
```

```
                ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE   1.1.4.1.2  ACS - CONDUCTORS & INSULATION

                INPUT PARAMETERS                                       INPUT COEFFICIENTS

   T=         2000.00000       TF=          1.000000           CDCER=           0.184860
   M=          500.000000      O&M=         0.0                CDEXP=           0.297000
  CF=            1.000000      Z1=          1.000000           CICER=           0.000005
 PHI=            1.000000      Z2=         60.000000           CIEXP=           1.000000
   R=            0.0           Z3=         60.000000           BYEAR=               1979
  DF=            0.100000      Z4=         60.000000    Z5=            0.0           Z6=          0.0

  CALCULATED VALUES            KG          SUM TO  1.1.4.1                        $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                     0.892

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                   0.002

#RM =T / M                                                                     4.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                 1.000

CTFU=(CLRM / E)X((#RM X  Z1+.5)XX(E) -0.5XX(E))                                       0.009

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3                    0.009

CIPS=CTB*Z4/Z2                                                                        0.009

   CRCI  =CTB  X R                                                                    0.0
          PRE-IOC  CRCI =CRCI X Z6                                                    0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                              0.0

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                       0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.158000     0.000004     0.0
   ASSOCIATED WITH ACS THRUSTER COMPLEXES
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.4.1.3 ACS - POWER PROCESSING EQUIPMENT

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	2000.00000	TF=	1.000000			CDCER=	0.184860		
M=	500.000000	U&M=	0.0			CDEXP=	0.297000		
CF=	1.000000	Z1=	1.000000			CICER=	0.000468		
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000		
R=	0.0	Z3=	60.000000			BYEAR=	1979		
DF=	0.500000	Z4=	60.000000	Z5=	0.0			Z6=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.4.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			1.438
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.234
#RM =T / M	4.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.936
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.936
CIPS=CTB*Z4/Z2			0.936
CRCI =CTB X R			0.0
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.0
CU&M =U&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1979 DATA ENTERED FOR CDCER,CICER, AND U&M WERE 0.184860 0.000468 0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.4.1.4 ALS - THRUSTER GIMBALS AND MOUNTING

```
                 INPUT PARAMETERS                                          INPUT COEFFICIENTS

   T=       2000.00000     TF=        1.000000            CDCER=          0.182520
   M=        500.000000   U&M=        0.0                 CDEXP=          0.511000
  CF=          1.000000    Z1=        1.000000            CICER=          0.000894
 PHI=          1.000000    Z2=       60.000000            CIEXP=          0.950000
   R=          0.0         Z3=       60.000000            BYEAR=              1979
  DF=          0.500000    Z4=       60.000000     Z5=          0.0           Z6=            0.0

 CALCULATED VALUES         KG        SUM TO  1.1.4.1                                  $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                       6.227

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                     0.328

#RM =T / M                                                                        4.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                    1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                          1.310


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))           ) / Z3                    1.310

CIPS=CTB*Z4/Z2                                                                          1.310

    CRCI  =CTB   X R                                                                    0.0
          PRE-IOC  CRCI =CRCI X Z6                                                      0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                                0.0

    CO&M  =U&M OR CTB*Z5/Z2/ENYR                                                        0.0

COMMENTS
    1979 DATA ENTERED FOR CDCER,CICER, AND U&M WERE     0.182520     0.000894     0.0
```

RUCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.4.2 ACSS PROPELLANT

INPUT PARAMETERS				INPUT COEFFICIENTS			
T=	1.000000	TF=	1.000000	CDCER=	0.0		
M=	1.000000	U&M=	0.099906	CDEXP=	0.0		
CF=	1.000000	Z1=	1.000000	CICER=	0.0		
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0		
R=	0.0	Z3=	60.000000	BYEAR=		1979	
DF=	1.000000	Z4=	60.000000	Z5=	0.0	Z6=	0.0

CALCULATED VALUES	SUM TO 1.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.0
#RM =T / M		1.000
E =1.0 + LOG(PHI) / LOG(2.0)		1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	) / Z3	0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
PRE-IOC CRCI =CRCI X Z6		0.0
POST-IOC CRCI =CRCI X (1.0-Z6)		0.0
CO&M =U&M OR CTB*Z5/Z2/ENYR		0.100

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.0 0.0 0.085390

O&M PROPELLANT ($1/KG-1977) = $1.17/KG AT 85390 KG/SAT/YR

1.1.5 COMMUNICATIONS

This element includes hardware to transmit and receive intelligence from among various SPS elements (satellite, construction and LEO base, transportation systems, ground receiving station). It includes communication of both data and voice between the SPS and the control center, as well as among various cargo and personnel vehicles. Excluded are intravehicular and intra-satellite communications.

1.1.6 INTERFACE (ENERGY CONVERSION/POWER TRANSMISSION)

This element covers the movable interface between the energy conversion subsystem and the power transmission subsystem. A 360 rotary joint and antenna elevation mechanism are required to maintain proper alignment of the transmitter with the ground receiving station. Included are structural items, mechanisms, power distribution, and maintenance hardware.

The interface is utilized to (1) transfer energy from the slip ring brushes to the antenna via transmission lines, and (2) act as the structural support member between the main satellite and the antenna. Elements of this movable interface (Figure 1.1-9) are described in the following subsections.

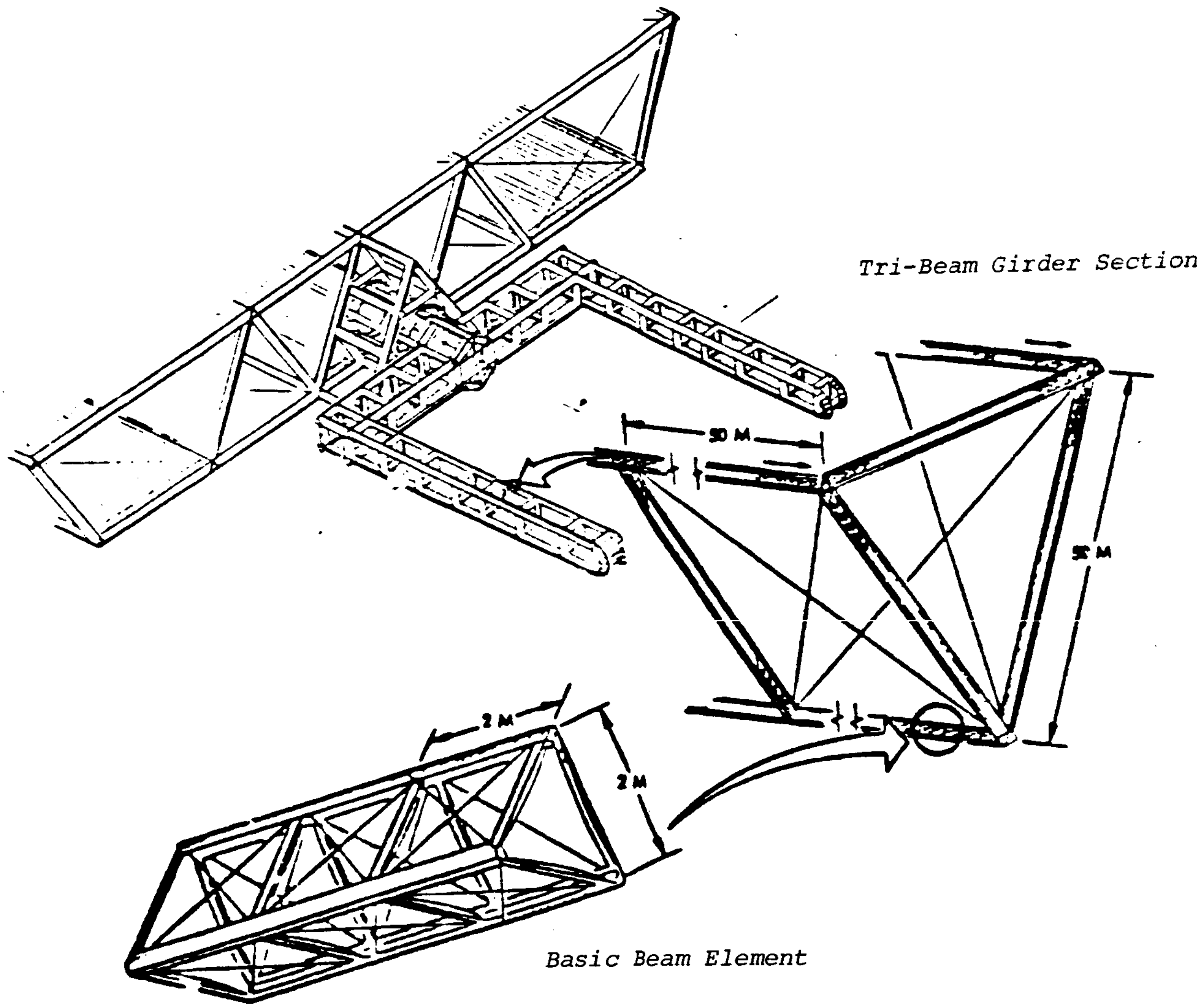


Figure 1.1-9. Energy Conversion/Power Transmission Interface

1.1.6.1 STRUCTURE

This element includes all members necessary to provide a mechanical interface between the primary structures of the energy conversion subsystem and the power transmisison subsystem. It includes beams, beam couplers, cables, tensioning devices, and secondary structures. Excluded are elements of the drive assembly which are included in mechanisms (WBS 1.1.6.2).

1.1.6.1.1 Primary Structure

The basic supporting structure of the interface is included in this element. It is the primary load-carrying structure and does not include the secondary structure that is required to support transmission buses or equipment.

The SPS requirement for low thermal distortion, under high thermal stress, dictates the need for a material with a very low coefficient of expansion. The most likely candidate, at this time, is a graphite composite material.

The interface primary structure D&D CER was developed using graphite composite data obtained from NASA's Redstar Data Base. Tooling cost was excluded under the assumption that this cost would be incurred in the development of orbital fabrication equipment. The following data points were used:

- Space telescope shell
- ATS-F truss
- HEAO optical bench
- Shuttle payload bay doors

The interface structure ICI is the cost of raw materials only, since the costs associated with fabrication and assembly are charged against orbital assembly and support equipment (WBS 1.2). The structure ICI cost equation is based on raw composite material stock (prepregnated graphite) cost. These material costs are based on vendor quotes obtained from Hercules, Fiberrite, and Union Carbide.

Range of Data:

D&D: 30.0 to 2000.0 kg
ICI: Unlimited

1.1.6.1.2 Secondary Structure

The secondary structure consists of the passive interface attachments between primary structure and operational subsystems. Structural members are made of aluminum with the ability to articulate, rotate, or otherwise support/allow motion between the primary structure and other subsystem elements.

This element includes all structure, consisting of mounting brackets, clamps, and installation structure required as an interface and mounting attach points of components, assemblies, and subsystems. It also includes any structure required between two or more components or assemblies, slip ring brush and wire support brackets, and mechanism supports.

Development of the secondary structure CER for DDT&E and ICI was based on cost data contained in the MSFC Redstar Data Base. Data from a variety of launch vehicle and unmanned satellite programs were available and the applicable data points are listed below:

- S-IVB interstage
- S-IC forward skirt
- S-IC intertank
- Solar telescope housing assembly (ASM)
- Common mount assembly (ASM)
- Telescope gimbal assembly (ASM)
- Common mount actuators (ASM)
- Telescope gimbal actuators (ASM)
- Array platform elevation pointing actuator (ASM)
- UV gimbal mount actuators (ASM)
- UV instrument mount assembly (ASM)
- Solar array and boom structure (ATS-F)
- Squib interface unit (ATS-F)
- Interstage (Centaur)
- Nose shroud (Centaur)
- Fixed airlock shroud (Skylab)
- Payload shroud (Skylab)
- Pallet segment (Spacelab)
- OSO-1
- ATS-F
- S-II

Range of Data:

DDT&E: 6.0 to 15,000.0 kg
ICI: 6.0 to 15,000.0 kg

A review of these data points indicates extrapolations at the 6-kg level were based on the ATS-F solar array and boom structure, the Squib interface unit, ASM gimbal assemblies and actuators; whereas, the S-IC inner-tank, Centaur nose shroud, and interstages were extrapolated for the 10,000-kg category. The design and size of these items are considered more complex than that required for the SPS and, as a result, a complexity factor (CF) of 0.80 was established for the pilot plant/test article and the COTV. A CF of 0.70 was used for the satellite as the two prior vehicles will be completed and an improved data base will be available for the satellite secondary structure.

Tooling factors were identified by grouping secondary structure requirements for the annual production of satellites (WBS 1.1.1.1.2, Energy Conversion; WBS 1.1.2.1.2, Power Transmission; and WBS 1.1.6.1.2, Interface).

1.1.6.1.3 Cost Estimates

Primary and secondary structure costs are presented in Tables 1.1.6.1.1 and 1.1.6.1.2, respectively.

```
                  ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
      TABLE    1.1.6.1.1   PRIMARY STRUCTURE

                     INPUT PARAMETERS                                    INPUT COEFFICIENTS

      T=      136000.000        TF=          1.000000            CDCER=          0.026910
      M=       17000.0000      O&M=          0.0                 CDEXP=          0.800000
     CF=           1.000000     Z1=          1.000000            CICER=          0.000058
    PHI=           1.000000     Z2=         60.000000            CIEXP=          1.000000
      R=           0.0          Z3=         60.000000            BYEAR=              1979
     DF=           0.010000     Z4=         60.000000    Z5=           0.0           Z6=          0.0

      CALCULATED VALUES            KG          SUM TO  1.1.6.1                         $,MILLIONS

   CD=CDCER X (T X DF)XX(CDEXP) X CF                                                    8.645

   CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                  0.994

   #RM =T / M                                                                       8.000

   E    =1.0 + LOG(PHI) / LOG(2.0)                                                  1.000

   CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                       7.956


   CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                  7.956

   CIPS=CTB*Z4/Z2                                                                       7.956

       CRCI  =CTB  X R                                                                  0.0
              PRE-IOC  CRCI =CRCI X Z6                                                  0.0
              POST-IOC CRCI =CRCI X (1.0-Z6)                                            0.0

       CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                     0.0

   COMMENTS
       1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.023000    0.000050     0.0
       OF CALCULATED INCOMBINATION WITH 1.1.1.1.1, 1.1.2.1.1, & 1.1.9.1.15,
       & 1.1.9.1.20
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.6.1.2 SECONDARY STRUCTURE

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	34000.0000	TF=	0.012296			CDCER=	0.182520
M=	5.000000	O&M=	0.0			CDEXP=	0.511000
CF=	0.700000	Z1=	1.000000			CICER=	0.118170
PHI=	0.980000	Z2=	60.000000			CIEXP=	0.355000
R=	0.001111	Z3=	62.000000			BYEAR=	1979
DF=	0.100000	Z4=	60.000000	Z5=	0.0	Z6=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.6.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			8.147
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.002
#RM =T / M			6800.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			9.753
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			8.648
CIPS=CTB*Z4/Z2			8.648
CRC1 =CTB X R			0.010
PRE-IOC CRC1 =CRC1 X Z6			0.0
POST-IOC CRC1 =CRC1 X (1.0-Z6)			0.010
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS
1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.156000 0.101000 0.0
COMBINE SATELLITE QUANTITIES FROM 1.1.1.1.2(117200 UNITS) & 1.1.2.1.2
(163000) FOR PHI DF & TF CALCULATIONS.

1.1.6.2 MECHANISMS

This element includes the components required to rotate and elevate power transmission (antenna) subsystem. Included are the drive ring, bearings, gear drives, and drive motors at the antenna connection.

Structural mechanisms consist of active and passive structural subassemblies that articulate, rotate, or otherwise cause or allow motion between the primary structure and other subsystem elements, or between subsystem elements themselves.

The ICI production cost CER was based on data provided by the following manufacturers:

Manufacturer	Application
Poly-Scientific	High energy
Poly-Scientific	Radar
Electro-Tec	Navy destroyer propeller system
Electro-Tec	Satellite solar array
I.E.C.	Navy shipboard hoist

Due to the difference in complexity and variations in specification requirements between ground- and space-qualified equipment, the following factors were applied:

Complexity factor	× 3
Specification uprating factor	× 3
Total	× 9

Range of Data:

DDT&E: 6.0 to 15,000 kg
ICI: 6.0 to 15,000 kg

Cost estimates for this element are shown in Table 1.1.6.2

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.6.2 MECHANISMS - INTERFACE

```
                INPUT PARAMETERS                                      INPUT COEFFICIENTS

   T=      33000.0000      TF=        1.000000         CDCER=          0.182520
   M=       1100.00000     O&M=       0.024999         CDEXP=          0.511000
  CF=          1.000000    Z1=        1.000000         CICER=          0.000894
 PHI=          0.980000    Z2=       60.000000         CIEXP=          0.950000
   R=          0.002222    Z3=       64.000000         BYEAR=             1979
  DF=          0.050000    Z4=       60.000000    Z5=          0.0         Z6=          0.0

  CALCULATED VALUES          KG           SUM TO  1.1.6                          $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                  8.043

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                0.693

#RM =T / M                                                                30.000

E    =1.0 + LOG(PHI) / LOG(2.0)                                            0.971

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                    19.337

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               17.173

CIPS=CTB*Z4/Z2                                                                    17.173

   CRCI  =CTB  X R                                                                 0.038
         PRE-IOC  CRCI =CRCI X Z6                                                  0.0
         POST-IOC CRCI =CRCI X (1.0-Z6)                                            0.038

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                    0.025

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.156000    0.000764    0.021367
   MECHANISMS ARE PRIMARILY PASSIVE GEARS AND BEARINGS AT ROTARY JOINT OF
   2000 KG. GIMBAL DRIVES & DRIVE MOTORS FOR THE ANTENNA ARE 31000 KG
```

1.1.6.3 POWER DISTRIBUTION

This element transmits electrical power from the rotary joint brushes to the microwave power transmission system (antenna). The PD&C system consists of power risers which are coupled to the pickup shoebrushes on the rotary joint and routed through the antenna support yolk (interface) to isolation switches on the antenna proper. There are two sets of slip rings, one positive and one negative; 15 brushes are needed per slip ring. Life expectancy of PD&C is 30 years with some replacements of slip ring brushes.

1.1.6.3.1 Conductors and Insulation

Power risers are sized to minimize the mass of itself and the satellite mass, considering power requirements, efficiency, and variation in resistivity with operating temperature. Power risers are made of multiple round aluminum (6101-T6) conductors with 1-mm kapton insulation, where 30 pairs of wire serve slip ring brushes.

1.1.6.3.2 Pickup Shoe Brushes

The pickup shoe brush portion of the rotary joint is included in the power distribution system of the interface segment. Sixty pickup shoe brush assemblies are required per satellite. The brush material is 75% m_0S_2 and 25% $M_0 \times Ta$ with a contact surface area per brush of 825.9 cm^2. The shoe dimension in cm is $20.3W \times 25H \times 152L$ with a total weight of 17,000 kg for 60 pickup shoe brushes.

1.1.6.3.3 Power Distribution Cost Estimates

The CER presented in Table 1.1.1.4.3 was used for conductors and insulation. An extension of this CER was used for the brushes of 1.1.6.3.2. Cost estimates for interface power distribution are presented in Tables 1.1.6.3.1 and 1.1.6.3.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.6.3.1 CONDUCTOR & INSULATION

```
                 INPUT PARAMETERS                                         INPUT COEFFICIENTS

   T=     271000.000      TF=        1.000000             CDCER=          0.184860
   M=      30.000000     U&M=        0.0                  CDEXP=          0.297000
  CF=       1.000000      Z1=        1.000000             CICER=          0.000005
 PHI=       1.000000      Z2=       60.000000             CIEXP=          1.000000
   R=       0.0           Z3=       60.000000             BYEAR=              1979
  DF=       0.100000      Z4=       60.000000     Z5=           0.0          Z6=           0.0

   CALCULATED VALUES        KG          SUM TO  1.1.6.3                       $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                              3.832

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                            0.000

#RM =T / M                                                                 9033.332

E    =1.0 + LOG(PHI) / LOG(2.0)                                              1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                 1.268


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3            1.268

CIPS=CTB*Z4/Z2                                                                 1.268

    CRC1  =CTB  X R                                                            0.0
          PRE-IOC  CRC1 =CRC1 X Z6                                             0.0
          POST-IOC CRC1 =CRC1 X (1.0-Z6)                                       0.0

    CU&M  =U&M OR CTB*Z5/Z2/ENYR                                               0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE     0.158000    0.000004    0.0
   30 PAIRS OF WIRE SERVING SLIPRINGS
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.6.3.2 SLIP RING BRUSHES

```
                 INPUT PARAMETERS                                    INPUT COEFFICIENTS

   T=      17000.0000     TF=        1.000000          CDCER=          0.184860
   M=        142.000000   O&M=       0.0               CDEXP=          0.297000
  CF=          1.000000   Z1=        1.000000          CICER=          0.000234
 PHI=          0.950000   Z2=       60.000000          CIEXP=          1.000000
   R=          0.005555   Z3=       70.000000          RYEAR=              1979
  DF=          0.020000   Z4=       60.000000   Z5=          0.0          Z6=          0.0

 CALCULATED VALUES             KG          SUM TO  1.1.6.3                   $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                               1.044

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                             0.033

#RM =T / M                                                                   119.718

E    =1.0 + LOG(PHI) / LOG(2.0)                                               0.926

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                  3.008


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3             2.201

CIPS=CTB*Z4/Z2                                                                  2.201

    CRC1   =CTB  X R                                                            0.012
             PRE-IOC   CRCI =CRCI X Z6                                          0.0
             POST-IOC  CRCI =CRCI X (1.0-Z6)                                    0.012

    CO&M   =O&M OR CTB*Z5/Z2/ENYR                                               0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.158000     0.000200     0.0
   30 SLIPRING SETS AT 4 SHOES EACH AVERAGE FOR M.
```

1.1.6.4 THERMAL CONTROL

This element includes any component used to modify the temperature of interface subsystem components. It includes coldplates, heat transfer, and radiator devices as well as insulation, thermal control coatings, and finishes. Excluded are paints or finishes applied to components during their manufacturing sequence. No thermal control requirements are defined for the interface at this time.

1.1.6.5 MAINTENANCE

This element provides for in-place repair or replacement of components and includes work stations, tracks, access ways, and *in situ* repair equipment on the interface (yoke) segment of the satellite.

Maintenance requirements are related to equipment and facilities needed to transport men and material to a work station on the interface segment of the satellite. Some of the same equipment required for maintenance at this location site is used commonly in the performance of work at other sites on the satellite.

Table 1.1.6.5 identifies the requirements. Cost estimates are provided in Tables 1.1.6.5.1, 1.1.6.5.2, and 1.1.6.5.3.

Table 1.1.6.5. Maintenance Requirements

WBS NO.	MAINTENANCE ITEM DESCRIPTION	1.1.6.5 INTERFACE
1.1.6.5.1	"FREE-FLYERS" OR BARGE FOR CARGO AND PERSONNEL (COMMON USE ITEM)	.2 VEHICLE UTILIZATION
1.1.6.5.2	MANNED MANIPULATOR MODULE	1 VEHICLE
1.1.6.5.3	TRACKS AND ACCESS WAYS	24000 kg

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.6.5.1 MAINTENANCE - FREE FLYERS

```
                 INPUT PARAMETERS                                    INPUT COEFFICIENTS

   T=      5000.00000     TF=       1.000000           CDCER=        0.0
   M=      5000.00000    O&M=       0.0                CDEXP=        0.0
  CF=         1.250000    Z1=       0.200000           CICER=        0.006784
 PHI=         0.950000    Z2=      60.000000           CIEXP=        1.000000
   R=         0.001111    Z3=      14.000000           BYEAR=           1979
  DF=         1.000000    Z4=      12.000000     Z5=          0.0          Z6=          0.0

  CALCULATED VALUES        KG         SUM TO  1.1.6.5                           $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                  0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               42.398

*RM =T / M                                                                      1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                  0.926

CTFU=(CLRM / E)X((*RM X Z1+.5)XX(E) -0.5XX(E))                                     8.810


CTB =((CLRM/E)X((*RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               37.186

CIPS=CTB*Z4/Z2                                                                     7.437

    CRCI  =CTB  X R                                                                0.041
          PRE-IOC  CRCI =CRCI X Z6                                                 0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                           0.041

    CU&M  =U&M OR CTB*Z5/Z2/ENYR                                                   0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0        0.005798    0.0
```

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.1.6.5.2   MANNED MANIPULATOR

                    INPUT PARAMETERS                                        INPUT COEFFICIENTS

     T=        3000.00000       TF=          1.000000             CDCER=           0.0
     M=        3000.00000      O&M=          0.0                  CDEXP=           0.0
    CF=           1.100000      Z1=          1.000000             CICER=           0.006784
   PHI=           0.950000      Z2=         60.000000             CIEXP=           1.000000
     R=           0.006666      Z3=         72.000000             BYEAR=              1979
    DF=           1.000000      Z4=         60.000000    Z5=            0.0           Z6=          0.0

     CALCULATED VALUES          KG         SUM TO  1.1.6.5                          $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                                     0.0

 CLRM=CICER X (M)XX(CIFXP) X CF X TF                                                  22.386

 #RM =T / M                                                                          1.000

 E    =1.0 + LOG(PHI) / LOG(2.0)                                                     0.926

 CTFU=(CLRM / E)X((#RM X  Z1+.5)XX(E) -0.5XX(E))                                      22.467

 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                  17.553

 CIPS=CTB*Z4/Z2                                                                       17.553

     CRCI   =CTB   X R                                                                 0.117
          PRE-IOC  CRCI  =CRCI X Z6                                                    0.0
          POST-IOC CRCI  =CRCI X (1.0-Z6)                                              0.117

     CO&M   =O&M OR CTB*Z5/Z2/ENYR                                                     0.0

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0        0.005798    0.0
```

```
               ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
    TABLE    1.1.6.5.3  TRACKS & ACCESS WAYS

                  INPUT PARAMETERS                              INPUT COEFFICIENTS

     T=      24000.0000     TF=        1.000000         CDCER=         0.0
     M=      24000.0000     O&M=       0.0              CDEXP=         0.0
    CF=          1.000000   Z1=        1.000000         CICER=         0.000058
   PHI=          1.000000   Z2=       60.000000         CIEXP=         1.000000
     R=          0.0        Z3=       60.000000         BYEAR=             1979
    DF=          1.000000   Z4=       60.000000    Z5=         0.0       Z6=          0.0

    CALCULATED VALUES           KG        SUM TO  1.1.6.5                  $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                          0.0

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                        1.404

  #RM =T / M                                                             1.000

  E   =1.0 + LOG(PHI) / LOG(2.0)                                         1.000

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                             1.404

  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))       ) / Z3           1.404

  CIPS=CTB*Z4/Z2                                                             1.404

    CRCI  =CTB  X R                                                          0.0
          PRE-IOC  CRCI =CRCI X Z6                                           0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                     0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                             0.0

  COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0       0.000050   0.0
```

1.1.7 SYSTEMS TEST

This element includes the hardware, software, and activities required for ground-based systems test including qualification tests and other development tests involving two or more subsystems or assemblies. It includes the production, assembly, integration, and checkout of satellite system hardware into a full or partial system test article. It also encompasses the design, development, and manufacture of special test equipment, test fixtures, and test facilities that are not included in other elements such as ground support facilities. Also included are planning, documentation, and actual test operations.

Table 1.1.7.1 documents DDT&E cost estimates for ground test hardware at 50% of satellite ICI costs. Operations for ground testing are assessed at another 50% of ICI costs as shown in Table 1.1.7.2.

RUCKWELL SPS CR-2 REFERENCE CONFIGURATION, 1980

TABLE 1.1.7.1 SYSTEM GROUND TEST HARDWARE

```
                      INPUT PARAMETERS                               INPUT COEFFICIENTS

      T=          0.0          TF=        1.000000          CDCER=          0.0
      M=          0.0         U&M=        0.0               CDEXP=          0.0
     CF=          0.0          Z1=        1.000000          CICER=          0.0
    PHI=          1.000000     Z2=       60.000000          CIEXP=          0.0
      R=          0.0          Z3=       60.000000          BYEAR=               1979
     DF=          1.00000C     Z4=       60.000000    Z5=         0.0            Z6=         0.0

    CALCULATED VALUES        SET          SUM TO  1.1.7                              $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 2489.092

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                   0.0

  #RM =T / M                                                                       0.0

  E   =1.0 + LOG(PHI) / LOG(2.0)                                                   0.0

  CIFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                        0.0


  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                   0.0

  CIPS=CTB*Z4/Z2                                                                        0.0

      CRCI   =CTB   X R                                                                 0.0
            PRE-IOC  CRCI =CRCI X Z6                                                    0.0
            POST-IOC CRCI =CRCI X (1.0-Z6)                                              0.0

      CO&M   =O&M OR CTB*Z5/Z2/ENYR                                                     0.0

  COMMENTS
      1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0          0.0        0.0
      DDT&E = 50% OF SATELLITE ICI
```

```
          ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE   1.1.7.2     SYSTEM GROUND TEST OPERATIONS

               INPUT PARAMETERS                              INPUT COEFFICIENTS

   T=        0.0           TF=        1.000000        CDCER=        0.0
   M=        0.0          O&M=        0.0             CDEXP=        0.0
  CF=        0.0           Z1=        1.000000        CICER=        0.0
 PHI=        1.000000      Z2=       60.000000        CIEXP=        0.0
   R=        0.0           Z3=       60.000000        BYEAR=           1979
  DF=        1.000000      Z4=       60.000000    Z5=         0.0      Z6=        0.0

   CALCULATED VALUES        SET         SUM TO  1.1.7                    $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                        2489.092

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                        0.0

#RM =T / M                                                             0.0

E   =1.0 + LOG(PHI) / LOG(2.0)                                         0.0

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                             0.0


CTR =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3          0.0

CIPS=CTB*Z4/Z2                                                             0.0

    CRCI  =CTB  X R                                                        0.0
           PRE-IOC  CRCI =CRCI X Z6                                        0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                  0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                           0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0      0.0      0.0
    DDT&E TEST OPS = 50% OF SATELLITE ICI
```

1.1.8 GROUND SUPPORT EQUIPMENT (GSE)

This element includes all ground-based hardware required in support of handling, servicing, test, and checkout of satellite subsystems. It also includes special hardware required for simulations and training.

Costs for design, development, manufacture, acceptance, qualification, and maintenance of the GSE equipment are included. It is recognized that various equipments can serve multipurposes. For example, a developmental mockup may later serve as a training aid after it has served its original purposes. In these instances, the acquisition cost is charged to the original or first-purpose use, and subsequent usage will incur only recurring operations and maintenance costs.

GSE costs from several launch vehicle, manned spacecraft and unmanned satellites were analyzed to determine their applicability to SPS GSE requirements. From these data, a percentage factor was developed which was used to estimate SPS ground support equipment costs. This factor is expressed by the equation $C_D = 0.10\ (C)$; where C = DDT&E cost of the satellite system. See table 1.1.8.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.8 GROUND SUPPORT EQUIPMENT- SATELLITE

```
                  INPUT PARAMETERS                                     INPUT COEFFICIENTS

   T=          0.0          TF=       1.000000          CDCER=          0.0
   M=          0.0          O&M=      0.0               CDEXP=          0.0
  CF=          0.0          Z1=       1.000000          CICER=          0.0
 PHI=          1.000000     Z2=      60.000000          CIEXP=          0.0
   R=          0.0          Z3=      60.000000          BYEAR=               1979
  DF=          1.000000     Z4=      60.000000    Z5=          0.0          Z6=        0.0

   CALCULATED VALUES        SET        SUM TO  1.1                          $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                            629.907

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                            0.0

#RM =T / M                                                                  0.0

E   =1.0 + LOG(PHI) / LOG(2.0)                                              0.0

CIFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                 0.0


CTR =((CLRM/E)X((#RM X   Z3 + 0.5)XX(E) -0.5XX(E))          ) / 23             0.0

CIPS=CTB*Z4/Z2                                                                 0.0

    CRC1  =CTB  X R                                                            0.0
          PRE-IOC  CRC1 =CRC1 X Z6                                             0.0
          POST-IOC CRC1 =CRC1 X (1.0-Z6)                                       0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                               0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0        0.0        0.0
    DDT&E   GSE = 10% OF SATELLITE DDT&E ABOVE
```

1.1.9 SPS PILOT PLANT AND TEST ARTICLE

This element of the SPS program consists of a pilot plant and test article to serve as a proof-of-concept (POC) for the Rockwell SPS reference configuration. It will have the objective to minimize overall costs of the program, and to maximize concept/system development activities before the commitment of extraordinary funds. At this same time, it is intended to validate space system technologies and to integrate energy conversion, interface, and power transmission segments of the SPS satellite. This leads to an operational capability that will combine program elements, transportation system interfaces, space construction techniques, and ground system operations.

Fundamentally, a total system proof of concept entails component manufacturing, launch to orbit, space construction, and system operation measurable to a performance specification. More specifically, it must involve validation from orbit of key technology issues. Where deemed necessary, full-scale system elements are to be employed. Funding for the demonstration must meet two basic requirements. First, the overall funding level shall be reasonably low, and achieve results commensurate with desired goals. Second, funding commitments shall also be conservative during the early time frame of the development programs, and still be compatible with the program schedule.

Completion of the SPS technology advancement phase of SPS research and development by 1987 will provide the technical confidence to proceed with full-scale pilot plant development and demonstration. Another objective of this development is to confirm test article performances and to demonstrate commercial viability of the SPS to sponsoring agencies, utility firms and potential consortiums, along with other interested groups that would ultimately interact with the production system and benefit from its capabilities. The proposed demonstration program, as shown in Figure 1.1-10, reflects, in general, the concept and phasing of this activity for cost-effective results and early design implementation.

The proof-of-concept test article would be constructed in LEO by using the Space Shuttle System (STS) for mass transfer and construction support. The construction of an antenna frame, initially to serve as a large structures demonstration article, is contemplated as the first step. LEO base facilities would be subsequently expanded to accommodate the buildup and fabrication of a single solar panel bay—equivalent in design to that contemplated for the satellite. A yoke is then fabricated at the solar bay and will serve as a mounting for the antenna frame. Subsequent assembly of antenna subarrays, solar panels, power distribution and conditioning, and other required subsystems will prepare the article for orbital checkout and initial test. The proof-of-concept satellite can be expanded by the addition of solar panel bays, and antenna subarrays as may be required for further LEO testing or as considered necessary for GEO test verification and operational checkout.

This element of the WBS covers those components of the pilot plant/test article program as needed to achieve end objectives. Subsequent sections describe cost and programmatic aspects in each area of the pilot plant as follows:

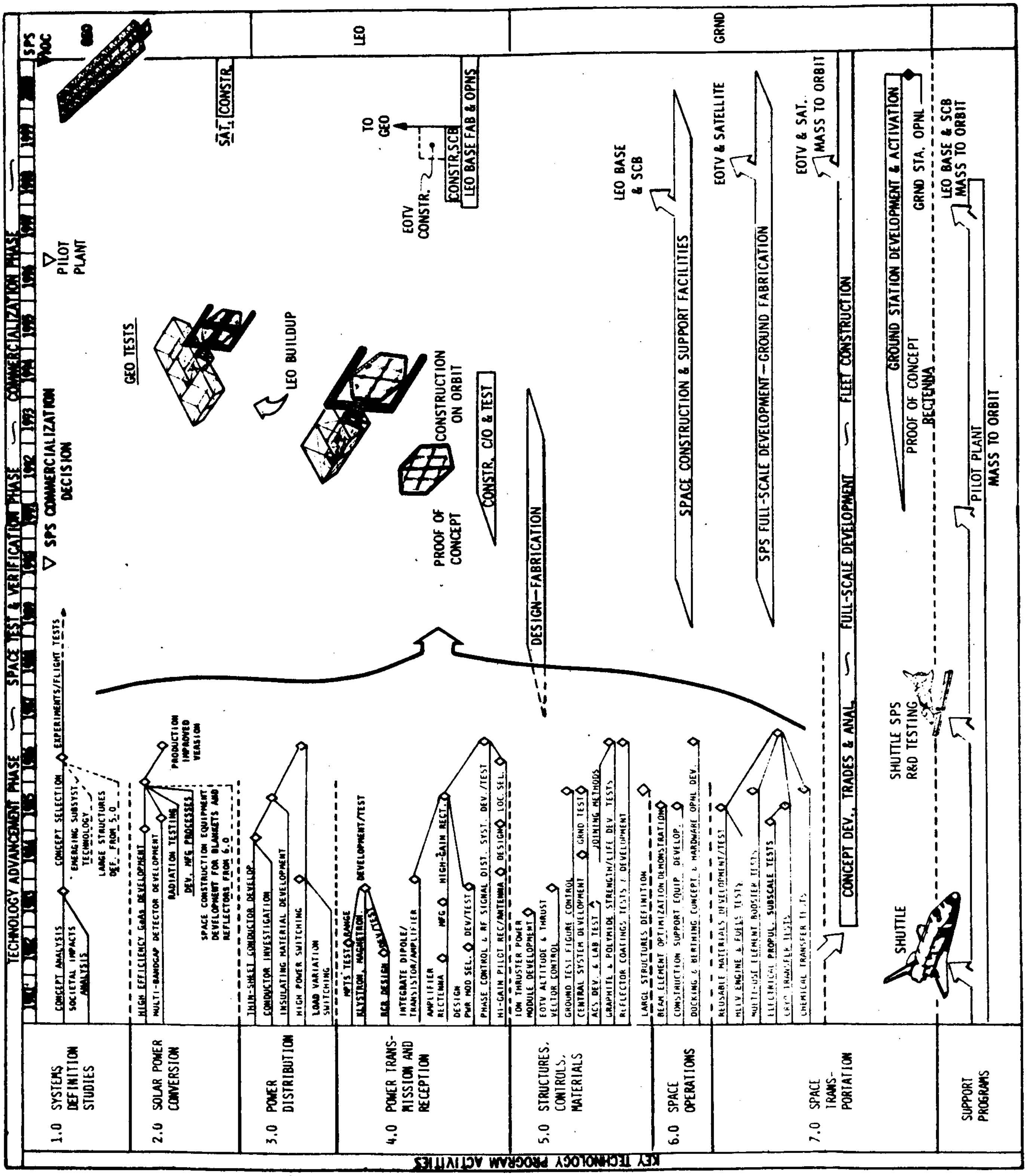


Figure 1.1-10. SPS Scenario—Planar Concept

- Energy conversion
- Interface segment
- Power transmission
- Supporting subsystems
- Construction/crew requirements
- Test and verification activities
- Pilot plant propellants
- Space Shuttle transportation requirements
- Ground receiving facility

1.1.9.1 PILOT PLANT AND TEST ARTICLE

This element covers procurement of energy conversion, interface, power transmission, and supporting system segments of the pilot plant/test article.

The energy conversion segment consists of primary and secondary structure, mechanisms, solar blankets and concentrators, power distribution and conditioning, attitude control and stationkeeping systems, slip rings at the yoke interface, tracks and accessories, and batteries for auxiliary power.

The interface or yoke segment between the planar array and antenna includes primary and secondary structure, mechanisms, power distribution and slip ring brushes.

Power transmission/antenna design requirements identify primary and secondary structure, mechanisms, power distribution and conditioning equipment, klystron subarrays, thermal control, batteries, information management system, and reference frequency generation systems. These items are covered in tables of cost data and calculations.

CER's and cost estimates in this section are based on those as used in the particular section or system of earlier sections of this volume. However, adjustments and changes in the use of equations have been made to hopefully compensate for technology status and production/space experience during this earlier period or phase of the SPS scenario. Estimates are established for DDT&E as considered necessary to arrive at specific system configurations applicable to the pilot plant/test article.

Cost estimates for this vehicle are presented in the following tables:

Table	Segment
1.1.9.1.1 through 1.1.9.1.14	Energy Conversion
1.1.9.1.15 through 1.1.9.1.19	Interface
1.1.9.1.20 through 1.1.9.1.49	Power Transmission

1.1.9.2 PILOT PLANT/TEST ARTICLE OPERATIONS

This element of the pilot plant/test article program covers the transportation aspects, space construction, test validation, and pilot plant propellant requirements.

Cost estimates are presented as follows:

Table	Item
1.1.9.2.1	Space Shuttle Transportation (STS)
1.1.9.2.2	Construction Crew
1.1.9.2.3	Test Verification
1.1.9.2.4	Pilot Plant Propellants

RUCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.1 PRIMARY STRUCTURE - E.C.

```
                  INPUT PARAMETERS                                        INPUT COEFFICIENTS

   T=     41000.0000      TF=       1.000000           CDCER=        0.026910
   M=        15.000000   U&M=       0.0                CDEXP=        0.800000
  CF=         1.000000    Z1=       1.000000           CICER=        0.000058
 PHI=         1.000000    Z2=      60.000000           CIEXP=        1.000000
   R=         0.0         Z3=       0.0                BYEAR=            1979
  DF=         0.500000    Z4=       0.0         Z5=          0.0          Z6=          0.0

  CALCULATED VALUES         KG          SUM TO  1.1.9.1                          $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                  75.738

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                 0.001

#RM =T / M                                                                 2733.333

E   =1.0 + LOG(PHI) / LOG(2.0)                                                1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                      2.398

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                0.0

CIPS=CTB*Z4/Z2                                                                      0.0

    CRCI  =CTB  X R                                                                 0.0
          PRE-IOC  CRCI =CRCI X Z6                                                  0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                            0.0

    CU&M  =U&M OR CTB*Z5/Z2/ENYR                                                    0.0

 COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE     0.023000    0.000050    0.0
    COMPOSITE MATERIAL.  DF CALCULATION CONSIDERS PRIMARY STRUCTURE
    FROM 1.1.9.1.15
```

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
   TABLE    1.1.9.1.2  SECONDARY STRUCTURE - E.C.

                INPUT PARAMETERS                                     INPUT COEFFICIENTS

     T=        56000.0000        TF=           0.032172          CDCER=           0.182520
     M=            5.000000      U&M=          0.0               CDEXP=           0.511000
    CF=            0.800000      Z1=           1.000000          CICER=           0.118170
   PHI=            1.000000      Z2=          60.000000          CIEXP=           0.355000
     R=            0.0           Z3=           0.0               BYEAR=               1979
    DF=            0.500000      Z4=          60.000000      Z5=           0.0       Z6=           0.0

    CALCULATED VALUES            KG           SUM TO   1.1.9.1                       $,MILLIONS

 CD=CDCER X (T X DF)XX(CDFXP) X CF                                                    27.346

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                   0.005

 #RM =T / M                                                                   11200.000

 E    =1.0 + LOG(PHI) / LOG(2.0)                                                  1.000

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                       60.315


 CTB =((CLRM/E)X((#RM X     Z3 + 0.5)XX(E) -0.5XX(E))           ) / Z3                 0.0

 CIPS=CTB*Z4/Z2                                                                        0.0

     CRCI  =CTB  X R                                                                   0.0
          PRE-IOC  CRCI =CRCI X Z6                                                     0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                               0.0

     CO&M  =U&M OR CTB*Z5/Z2/ENYR                                                      0.0

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE      0.156000    0.101000    0.0
     COMBINE OTHER PRECURSOR QUANTITIES FROM 1.1.9.1.16 & 1.1.9.1.21 FOR
     DF & TF CALCULATIONS. COVERS THRUSTER STRUCTURES PLUS SECONDARY
     STRUCTURE
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.3 MECHANISMS - PRECURSOR E.C.

INPUT PARAMETERS					INPUT COEFFICIENTS	
T=	10000.0000	TF=	1.000000		CDCER=	0.182520
M=	110.000000	U&M=	0.0		CDEXP=	0.511000
CF=	1.500000	Z1=	1.000000		CICER=	0.000894
PHI=	1.000000	Z2=	60.000000		CIEXP=	0.950000
R=	0.0	Z3=	0.0		BYEAR=	1979
DF=	0.500000	Z4=	60.000000	Z5= 0.0	Z6=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			21.261
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.117
#RM =T / M	90.909		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			10.600
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.0
CO&M =U&M OR CTP*Z5/Z2/ENYR			0.0

COMMENTS
1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE 0.156000 0.000764 0.0
INCLUDES 4000 KG FOR ROTARY JOINT MOTORS/DEVICES, TENSION DEVICES,
PAYLOAD LATCHES, THRUSTOR GIMBOLS

```
            ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE    1.1.9.1.4  CONCENTRATOR - E.C.

              INPUT PARAMETERS                                INPUT COEFFICIENTS

   T=     1823200.00        TF=         1.000000        CDCER=          0.031590
   M=      474500.000      O&M=         0.0             CDEXP=          0.394000
  CF=         1.000000      Z1=         1.000000        CICER=          0.000004
 PHI=         1.000000      Z2=        60.000000        CIEXP=          0.950000
   R=         0.0           Z3=         0.0             BYEAR=              1979
  DF=         1.000000      Z4=         0.0        Z5=         0.0        Z6=         0.0

  CALCULATED VALUES        SQ M          SUM TO  1.1.9.1                    $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                             9.254

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                           0.866

#RM =T / M                                                                3.842

E   =1.0 + LOG(PHI) / LOG(2.0)                                            1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                3.329


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3          0.0

CIPS=CTB*Z4/Z2                                                                0.0

    CRCI   =CTB   X R                                                         0.0
           PRE-IOC  CRCI =CRCI X Z6                                           0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                     0.0

    CO&M   =O&M OR CTB*Z5/Z2/ENYR                                             0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.027000    0.000003    0.0
    DENSITY = .0181 KG PER SQ METER MASS = 33000 KG
```

```
                 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE   1.1.9.1.5  SOLAR BLANKET -E.C.

                 INPUT PARAMETERS                                  INPUT COEFFICIENTS

  T=      949000.000      TF=         1.000000          CDCER=        0.188838
  M=       15250.0000     O&M=        0.0               CDEXP=        0.394000
 CF=           1.200000   Z1=         1.000000          CICER=        0.000078
PHI=           1.000000   Z2=        60.000000          CIEXP=        1.000000
  R=           0.0        Z3=         0.0               RYEAR=           1979
 DF=           2.000000   Z4=         0.0        Z5=          0.0         Z6=          0.0

 CALCULATED VALUES        SQ M        SUM TO  1.1.9.1                        $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                               67.440

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                              1.717

#RM =T / M                                                                     52.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                  1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                  89.271


CTB =((CLRM/E)X((#RM X   Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3                0.0

CIPS=CTB*Z4/Z2                                                                  0.0

   CRCI  =CTB  X R                                                              0.0
        PRE-IOC  CRCI =CRCI X Z6                                                0.0
        POST-IOC CRCI =CRCI X (1.0-Z6)                                          0.0

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                 0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.161400    0.000067    0.0
   DENSITY - 0.2525 KG PER SQ M, 2 SECTIONS, 26 PANELS EACH.
   SECTION=650M X 73CM
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.6 SWITCHGEAR & REGULATORS - E.C.

```
                 INPUT PARAMETERS                                      INPUT COEFFICIENTS

  T=       9700.00000     TF=        1.000000          CDCER=           0.184860
  M=        186.000000    O&M=       0.0               CDEXP=           0.297000
 CF=          1.500000    Z1=        1.000000          CICER=           0.000468
PHI=          1.000000    Z2=       60.000000          CIEXP=           1.000000
  R=          0.0         Z3=        0.0               BYEAR=               1979
 DF=          2.000000    Z4=        0.0        Z5=          0.0           Z6=            0.0

  CALCULATED VALUES          KG          SUM TO  1.1.9.1                          $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                   5.205

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                 0.131

#RM =T / M                                                                52.151

E   =1.0 + LOG(PHI) / LOG(2.0)                                            1.000

CIFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                      6.809

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))            ) / Z3               0.0

CIPS=CTB*Z4/Z2                                                                      0.0

    CRCI  =CTB  X R                                                                 0.0
          PRE-IOC  CRCI =CRCI X Z6                                                  0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                            0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                    0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.158000    0.000400    0.0
    1 BAY (2 SECTIONS) WITH 26 SETS PER SECTION.  INCLUDES 2000 KG FOR
    ACS POWER PROCESSING
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.7 LO-VOLTAGE CONVERTERS - E.C

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	300.000000	TF=	1.000000			CDCER=	0.184860
M=	6.000000	O&M=	0.0			CDEXP=	0.297000
CF=	1.500000	Z1=	1.000000			CICER=	0.000468
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	0.0			BYEAR=	1979
DF=	2.000000	Z4=	60.000000	Z5=	0.0	Z6=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			1.854
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.004
#RM =T / M		50.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.211
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS
1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.158000 0.000400 0.0
1 BAY (2 SECTIONS) WITH 26 SETS PER SECTION.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE 1.1.9.1.8 CONDUCTORS & INSULATION - E.C.

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	259000.000	TF=	1.000000		CDCER=	0.184860	
M=	4980.00000	O&M=	0.0		CDEXP=	0.297000	
CF=	1.000000	Z1=	1.000000		CICER=	0.000005	
PHI=	1.000000	Z2=	60.000000		CIEXP=	1.000000	
R=	0.0	Z3=	0.0		BYEAR=	1979	
DF=	1.000000	Z4=	0.0	Z5= 0.0		Z6=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			7.492
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.023
#RM =T / M	52.008		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.212
CTR =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.0
COGM =O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS
1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.158000 0.000004 0.0
1 BAY (2 SECTIONS) WITH 26 SETS PER SECTION ON ARRAY

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.9 ACS HARDWARE - E.C.

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	109000.000	TF=	0.300000			CDCER=	1.312739
M=	908.000000	O&M=	0.0			CDEXP=	0.190000
CF=	1.000000	Z1=	1.000000			CICER=	0.066690
PHI=	1.000000	Z2=	60.000000			CIEXP=	0.729000
R=	0.0	Z3=	0.0			BYEAR=	1979
DF=	1.000000	Z4=	0.0	Z5=	0.0	Z6=	0.0

```
CALCULATED VALUES            KG        SUM TO  1.1.9.1              $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                       11.893

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                      2.868

#RM =T / M                                                     120.044

E   =1.0 + LOG(PHI) / LOG(2.0)                                   1.000

CIFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                         344.323

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))      ) / Z3         0.0

CIPS=CTB*Z4/Z2                                                           0.0

   CRCI   =CTB  X R                                                      0.0
          PRE-IOC  CRCI =CRCI X Z6                                       0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                 0.0

   CO&M   =O&M OR CTB*Z5/Z2/ENYR                                         0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE    1.122000   0.057000   0.0
   ITEM INCLUDES 120 THRUSTERS, TANKS, PROPELLANT LINES, AND ATTITUDE
   REFER. DETER. SYSTEM
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.10 ACS - CONDUCTORS & INSUL - E.C.

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	5920.00000	TF=	1.000000			CDCER=	0.184860
M=	1480.00000	O&M=	0.0			CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000			CICER=	0.000005
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	0.0			BYEAR=	1979
DF=	1.000000	Z4=	60.000000	Z5=	0.0	Z6=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			2.439
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.007
#RM =T / M			4.000
E =1.0 + LOG(PHI) / LOG(2.0)			1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.030
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRC1 =CTB X R			0.0
PRE-IOC CRC1 =CRC1 X Z6			0.0
POST-IOC CRC1 =CRC1 X (1.0-Z6)			0.0
COGM =O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1979 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.184860 0.000005 0.0

CONDUCTORS ASSOCIATED WITH ACS SYSTEM OF 4 THRUSTER COMPLEXES

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.11 ACS - BATTERIES - E.C.

INPUT PARAMETERS					INPUT COEFFICIENTS	
T=	152000.000	TF=	0.140000		CDCER=	0.040145
M=	50.000000	U&M=	0.0		CDEXP=	0.734000
CF=	1.500000	Z1=	1.000000		CICER=	0.030380
PHI=	1.000000	Z2=	60.000000		CIEXP=	0.241000
R=	0.0	Z3=	0.0		BYEAR=	1979
DF=	0.005000	Z4=	60.000000	Z5= 0.0	Z6=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			7.839
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.016
#RM =T / M	3040.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			49.789
CIB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.0
CO&M =U&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1978 DATA ENTERED FOR CDCER,CICER, AND U&M WERE 0.037000 0.028000 0.0
50 KG PER CELL. CF CONSIDERS SODIUM CHLORIDE VS DATA BASE.
INCLUDES BATTERIES FOR E.C. SEGMENT, TF BASED ON 10 CELLS/BATTERY

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.12 ACS - BATTERY PD&C - E.C.

```
                INPUT PARAMETERS                                    INPUT COEFFICIENTS

   T=     2000.00000      TF=      1.000000          CDCER=         0.057505
   M=      250.000000     O&M=     0.0               CDEXP=         0.890000
  CF=        1.000000     Z1=      1.000000          CICER=         0.013020
 PHI=        1.000000     Z2=     60.000000          CIEXP=         0.659000
   R=        0.0          Z3=      0.0               BYEAR=             1979
  DF=        0.250000     Z4=     60.000000    Z5=          0.0        Z6=           0.0

  CALCULATED VALUES       KG          SUM TO  1.1.9.1                  $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                        14.514

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                       1.494

#RM =T / M                                                             8.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                         1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                           11.954


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))       ) / Z3          0.0

CIPS=CTB*Z4/Z2                                                            0.0

    CRCI  =CTB  X R                                                       0.0
         PRE-IOC  CRCI =CRCI X Z6                                         0.0
         POST-IOC CRCI =CRCI X (1.0-Z6)                                   0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                          0.0

COMMENTS
    1976 DATA ENTERED FOR CDCER,CICER, AND O&M WERE    0.053000   0.012000   0.0
    SEE 1.1.9.1.35 FOR ADDITIONAL DDT&E
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.13 SLIPRINGS - PRECURSOR E.C.

```
                    INPUT PARAMETERS                                       INPUT COEFFICIENTS

   T=      1500.00000      TF=        1.000000             CDCER=         0.182520
   M=       750.000000    O&M=        0.0                  CDEXP=         0.511000
  CF=         2.000000     Z1=        1.000000             CICER=         0.000894
 PHI=         1.000000     Z2=       60.000000             CIEXP=         0.950000
   R=         0.0          Z3=        0.0                  BYEAR=             1979
  DF=         3.000000     Z4=        0.0          Z5=          0.0            Z6=          0.0

  CALCULATED VALUES          KG         SUM TO  1.1.9.1                        $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                              26.862

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                             0.963

 #RM =T / M                                                                    2.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                                1.000

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                  1.926


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3            0.0

 CIPS=CTB*Z4/Z2                                                                  0.0

    CRCI  =CTB  X R                                                              0.0
          PRE-IOC  CRCI =CRCI X Z6                                               0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                         0.0

    COGM  =O&M OR CTB*Z5/Z2/ENYR                                                 0.0

 COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.156000     0.000764     0.0
    ONE FULL SLIP RING SET ONLY
```

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.1.9.1.14 TRACKS & ACCESS WAYS - E.C.

                     INPUT PARAMETERS                                    INPUT COEFFICIENTS

      T=       35000.0000       TF=          1.000000         CDCER=          0.0
      M=        100.000000     O&M=          0.0              CDEXP=          0.0
     CF=          1.000000      Z1=          1.000000         CICER=          0.000058
    PHI=          1.000000      Z2=         60.000000         CIEXP=          1.000000
      R=          0.0           Z3=          0.0              BYEAR=              1979
     DF=          1.000000      Z4=         60.000000    Z5=          0.0         Z6=          0.0

     CALCULATED VALUES           KG         SUM TO  1.1.9.1                    $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                              0.0

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                            0.006

  *RM =T / M                                                                 350.000

  E    =1.0 + LOG(PHI) / LOG(2.0)                                              1.000

  CTFU=(CLRM / E)X((*RM X Z1+.5)XX(E) -0.5XX(E))                                 2.047


  CTB =((CLRM/E)X((*RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3             0.0

  CIPS=CTB*Z4/Z2                                                                 0.0

     CRCI   =CTB   X R                                                           0.0
            PRE-IOC  CRCI =CRCI X Z6                                             0.0
            POST-IOC CRCI =CRCI X (1.0-Z6)                                       0.0

     CO&M   =O&M OR CTB*Z5/Z2/ENYR                                               0.0

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0        0.000050    0.0
     TOTAL OF 35000 KG COVERS 3000 KG FOR E.C. AND 32000 KG FOR INTERFACE
```

```
                 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE   1.1.9.1.15 PRIMARY STRUCTURE - INTERFACE

              INPUT PARAMETERS                                  INPUT COEFFICIENTS

   T=     136000.000      TF=        1.000000          CDCER=         0.026910
   M=        200.000000   UGM=       0.0               CDEXP=         0.600000
  CF=          1.000000   Z1=        1.000000          CICER=         0.000058
 PHI=          1.000000   Z2=       60.000000          CIEXP=         1.000000
   R=          0.0        Z3=        0.0               BYEAR=            1979
  DF=          0.500000   Z4=        0.0        Z5=          0.0          Z6=        0.0

  CALCULATED VALUES         KG         SUM TO  1.1.9.1                       $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                             197.661

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                             0.012

#RM =T / M                                                                  680.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                 1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                  7.956


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3               0.0

CIPS=CTB*Z4/Z2                                                                  0.0

   CRCI  =CTB  X R                                                              0.0
         PRE-IOC  CRCI =CRCI X Z6                                               0.0
         POST-IOC CRCI =CRCI X (1.0-Z6)                                         0.0

   CO&M  =UGM OR CTB*Z5/Z2/ENYR                                                 0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND UGM WERE     0.023000    0.000050     0.0
   COMPOSITE MATERIAL.  DF CALCULATION CONSIDERS PRIMARY STRUCTURE
   FROM 1.1.9.1.1
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.16 SECONDARY STRUCTURE - INTERFACE

```
                 INPUT PARAMETERS                                  INPUT COEFFICIENTS

   T=       6000.00000     TF=        0.032172             CDCER=         0.182520
   M=          5.000000    O&M=       0.0                  CDEXP=         0.511000
  CF=          0.800000    Z1=        1.000000             CICER=         0.118170
 PHI=          1.000000    Z2=       60.000000             CIEXP=         0.355000
   R=          0.0         Z3=        0.0                  BYEAR=            1979
  DF=          0.500000    Z4=       60.000000      Z5=           0.0         Z6=           0.0

   CALCULATED VALUES        KG        SUM TO  1.1.9.1                         $,MILLIONS

CD=CDCER X (1 X DF)XX(CDEXP) X CF                                               8.734

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                             0.005

#RM =T / M                                                               1200.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                              1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                  6.462


CIB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3              0.0

CIPS=CTB*Z4/Z2                                                                  0.0

    CRCI  =CTB  X R                                                             0.0
          PRE-IOC  CRCI =CRCI X Z6                                              0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                        0.0

    CU&M  =U&M OR CTB*Z5/Z2/ENYR                                                0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.156000    0.101000    0.0
    COMBINE OTHER PRECURSOR QUANTITIES FROM 1.1.9.1.2 & 1.1.9.1.21
    FOR DF & TF CALCULATIONS.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.17 MECHANISMS - INTERFACE

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	33000.0000	TF=	1.000000			CDCER=	0.182520
M=	1100.00000	O&M=	0.0			CDEXP=	0.511000
CF=	1.500000	Z1=	1.000000			CICER=	0.000894
PHI=	1.000000	Z2=	60.000000			CIEXP=	0.950000
R=	0.0	Z3=	0.0			BYEAR=	1979
DF=	0.100000	Z4=	0.0	Z5=	0.0	Z6=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			17.193
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.039
#RM =T / M		30.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			31.176
CTR =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTR*Z4/Z2			0.0
CRCI =CTB X R			0.0
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.156000 0.000764 0.0

T INCLUDES 3100 KG FOR GIMBAL DRIVE MOTORS/DEVICES AND 2000 KG FOR GEARS & BEARINGS

```
            ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE   1.1.9.1.18 CONDUCTORS & INSULATION - INTERFACE

              INPUT PARAMETERS                                   INPUT COEFFICIENTS

   T=       9500.00000    TF=        1.000000          CDCER=          0.184860
   M=       1200.00000    O&M=       0.0               CDEXP=          0.297000
  CF=          1.000000   Z1=        1.000000          CICER=          0.000005
 PHI=          1.000000   Z2=       60.000000          CIEXP=          1.000000
   R=          0.0        Z3=        0.0               BYEAR=              1979
  DF=          1.000000   Z4=        0.0        Z5=          0.0           Z6=          0.0

   CALCULATED VALUES          KG        SUM TO   1.1.9.1                    $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                            2.807

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                          0.006

#RM =T / M                                                               7.917

E    =1.0 + LOG(PHI) / LOG(2.0)                                          1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                               0.044


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3          0.0

CIPS=CTB*Z4/Z2                                                             0.0

   CRCI   =CTB  X R                                                        0.0
        PRE-IOC  CRCI =CRCI X Z6                                           0.0
        POST-IOC CRCI =CRCI X (1.0-Z6)                                     0.0

   CO&M   =O&M OR CTB*Z5/Z2/ENYR                                           0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.158000    0.000004    0.0
```

```
                 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
      TABLE   1.1.9.1.19 SLIPRING BRUSHES - PRECURSOR - INTERFACE

                  INPUT PARAMETERS                                INPUT COEFFICIENTS

    T=        500.000000     TF=        1.000000          CDCER=          0.184860
    M=        125.000000    O&M=        0.0               CDEXP=          0.297000
   CF=          1.000000     Z1=        1.000000          CICER=          0.000234
  PHI=          1.000000     Z2=       60.000000          CIEXP=          1.000000
    R=          0.0          Z3=        0.0               BYEAR=              1979
   DF=          1.000000     Z4=        0.0        Z5=          0.0        Z6=          0.0

    CALCULATED VALUES            KG         SUM TO  1.1.9.1                      $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                                1.171

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                              0.029

 *RM =T / M                                                                 4.000

 E    =1.0 + LOG(PHI) / LOG(2.0)                                            1.000

 CTFU=(CLRM / E)X((*RM X Z1+.5)XX(E) -0.5XX(E))                                   0.117


 CTB =((CLRM/E)X((*RM X     Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3             0.0

 CIPS=CTB*Z4/Z2                                                                   0.0

     CRC1  =CTB  X R                                                              0.0
         PRE-IOC  CRC1 =CRC1 X Z6                                                 0.0
         POST-IOC CRC1 =CRC1 X (1.0-Z6)                                           0.0

     CO&M  -O&M OR CTF*Z5/Z2/ENYR                                                 0.0

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.158000    0.000200    0.0
     SET OF BRUSHES FOR ONE SLIP RING ONLY
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.20 PRIMARY STRUCTURE - POWER TRANS

```
              INPUT PARAMETERS                                       INPUT COEFFICIENTS

    T=     23000.0000      TF=      1.000000          CDCER=        0.026910
    M=      3800.00000     O&M=     0.0               CDEXP=        0.800000
   CF=         1.000000    Z1=      1.000000          CICER=        0.000058
  PHI=         1.000000    Z2=     60.000000          CIEXP=        1.000000
    R=         0.0         Z3=      0.0               BYEAR=            1979
   DF=         0.200000    Z4=      0.0        Z5=          0.0         Z6=        0.0

   CALCULATED VALUES       KG      SUM TO  1.1.9.1                    $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                       22.915

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                      0.222

#RM =T / M                                                           6.053

E   =1.0 + LOG(PHI) / LOG(2.0)                                       1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                           1.345


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3       0.0

CIPS=CTB*Z4/Z2                                                          0.0

    CRC1  =CTB  X R                                                     0.0
          PRE-IOC  CRC1 =CRC1 X Z6                                      0.0
          POST-IOC CRC1 =CRC1 X (1.0-Z6)                                0.0

    COGM  =O&M OR CTB*Z5/Z2/ENYR                                        0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE    0.023000    0.000050    0.0
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.21 SECONDARY STRUCTURE - POWER TRANS

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	29900.0000	TF=	0.032172			CDCER=	0.182520		
M=	5.000000	O&M=	0.0			CDEXP=	0.511000		
CF=	0.800000	Z1=	1.000000			CICER=	0.118170		
PHI=	1.000000	Z2=	60.000000			CIEXP=	0.355000		
R=	0.0	Z3=	0.0			BYEAR=	1979		
DF=	0.500000	Z4=	60.000000	Z5=	0.0		Z6=		0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			19.845
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.005
#RM =T / M	5980.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			32.204
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.0
COGM =O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.156000 0.101000 0.0
COMBINE OTHER PRECURSOR QUANTITIES FROM 1.1.9.1.2 & 1.1.9.1.16 FOR
DF & TF CALCULATIONS

```
              ROCKWELL SPS CP-2 REFERENCE CONFIGURATION,1980
  TABLE    1.1.9.1.22 MECHANISMS - POWER TRANS.

                INPUT PARAMETERS                             INPUT COEFFICIENTS

     T=      2000.00000     TF=       1.000000         CDCER=        0.182520
     M=      1000.00000    U&M=       0.0              CDEXP=        0.511000
    CF=         1.500000    Z1=       1.000000         CICER=        0.000894
   PHI=         1.000000    Z2=      60.000000         CIEXP=        0.950000
     R=         0.0         Z3=       0.0              BYEAR=            1979
    DF=         1.000000    Z4=      60.000000    Z5=        0.0      Z6=          0.0

  CALCULATED VALUES          KG          SUM TO  1.1.9.1                 $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                          13.312

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                         0.949

#RM =T / M                                                              2.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                          1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                              1.899


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))       ) / Z3            0.0

CIPS=CTB*Z4/Z2                                                              0.0

   CRCI   =CTB   X R                                                        0.0
        PRE-IOC  CRCI =CRCI X Z6                                            0.0
        POST-IOC CRCI =CRCI X (1.0-Z6)                                      0.0

   CO&M   =U&M OR CTB*Z5/Z2/ENYR                                            0.0

COMMENTS
   1979 DATA ENTERED FOR CDCER,CICER, AND U&M WERE    0.182520   0.000894   0.0
   GEARS & BEARINGS LOCATED AT ANTENNA TRUNNIONS
```

```
                  ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.1.9.1.23 P.T. KLYSTRON SUBARRAY DDT&E

                  INPUT PARAMETERS                               INPUT COEFFICIENTS

     T=      252000.000       TF=          1.000000         CDCER=           0.078390
     M=          48.000000    O&M=         0.0              CDEXP=           0.507000
    CF=           1.500000    Z1=          1.000000         CICER=           0.0
   PHI=           1.000000    Z2=         60.000000         CIEXP=           0.0
     R=           0.0         Z3=          0.0              BYEAR=              1979
    DF=           2.000000    Z4=         60.000000    Z5=           0.0         Z6=          0.0

     CALCULATED VALUES          KW         SUM TO  1.1.9.1                       $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 91.513

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                0.0

 #RM =T / M                                                                      5250.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                                     1.000

 CTFU=(CLRM / E)X((#RM X  Z1+.5)XX(E) -0.5XX(E))                                     0.0


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                 0.0

 CIPS=CTB*Z4/Z2                                                                      0.0

     CRCI  =CTB  X R                                                                 0.0
           PRE-IOC  CRCI =CRCI X Z6                                                  0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                            0.0

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                    0.0

 COMMENTS
     1979 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.078390    0.0        0.0
     5250 KLYSTRONS ON PRECURSOR WITH OPERATION AT 48 KW PER TUBE
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.24 P.T. KLYSTRON WAVEGUIDE

```
              INPUT PARAMETERS                                   INPUT COEFFICIENTS

   T=     5250.00000      TF=      1.000000          CDCER=          0.0
   M=        9.000000    O&M=      0.0               CDEXP=          0.0
  CF=        1.200000     Z1=      1.000000          CICER=          0.000348
 PHI=        1.000000     Z2=     60.000000          CIEXP=          1.000000
   R=        0.0          Z3=      0.0               BYEAR=             1979
  DF=        1.000000     Z4=     60.000000    Z5=          0.0          Z6=          0.0

   CALCULATED VALUES     PM SET          SUM TO  1.1.9.1                        $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                  0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                0.004

#RM =T / M                                                                     583.333

E   =1.0 + LOG(PHI) / LOG(2.0)                                                   1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                     2.192


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                0.0

CIPS=CTB*Z4/Z2                                                                     0.0

    CRCI  =CTB  X R                                                                0.0
           PRE-IOC  CRCI =CRCI X Z6                                                0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                          0.0

    COEM  =O&M OR CTB*Z5/Z2/ENYR                                                   0.0

COMMENTS
    1979 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0         0.000348     0.0
    5250 KLYSTRONS WITHIN 9 DENSITY GRADIENTS. ONE EQUIVALENT WAVEGUIDE EACH
    PER 5250 COST ELEMENTS.
```

```
                ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
   TABLE   1.1.9.1.25 P.T. KLYSTRON HEATPIPES

                INPUT PARAMETERS                              INPUT COEFFICIENTS

     T=     5250.00000     TF=        1.000000        CDCER=          0.0
     M=        9.000000    O&M=       0.0             CDEXP=          0.0
    CF=        1.200000    Z1=        1.000000        CICER=          0.003006
   PHI=        1.000000    Z2=       60.000000        CIEXP=          1.000000
     R=        0.0         Z3=        0.0             RYEAR=             1979
    DF=        1.000000    Z4=       60.000000   Z5=         0.0         Z6=        0.0

   CALCULATED VALUES      PM SET          SUM TO  1.1.9.1                   $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                              0.0

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                            0.032

 #RM =T / M                                                                   583.333

 E   =1.0 + LOG(PHI) / LOG(2.0)                                                 1.000

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                18.938


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3            0.0

 CIPS=CTB*Z4/Z2                                                                 0.0

   CRCI  =CTB  X R                                                              0.0
         PRE-IOC  CRCI =CRCI X Z6                                               0.0
         POST-IOC CRCI =CRCI X (1.0-Z6)                                         0.0

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                 0.0

 COMMENTS
   1979 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0         0.003006    0.0
   5250 KLYSTRONS WITHIN 9 DENSITY GRADIENTS.  ONE SET OF HEAT PIPES PER
   5250 COST ELEMENTS
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.26 P.T. KLYSTRON P.M. ELEMENT

```
                    INPUT PARAMETERS                                   INPUT COEFFICIENTS

   T=       5250.00000      TF=          1.000000          CDCER=            0.0
   M=          1.000000     O&M=         0.0               CDEXP=            0.0
  CF=          1.200000     Z1=          1.000000          CICER=            0.002340
 PHI=          1.000000     Z2=         60.000000          CIEXP=            1.000000
   R=          0.0          Z3=          0.0               BYEAR=               1979
  DF=          1.000000     Z4=         60.000000   Z5=          0.0        Z6=          0.0

  CALCULATED VALUES        PM SET         SUM TO  1.1.9.1                     $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                               0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                             0.003

#RM =T / M                                                                   5250.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                  1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                 14.742


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3            0.0

CIPS=CTB*Z4/Z2                                                                  0.0

    CRCI  =CTB  X R                                                             0.0
          PRE-IOC  CRCI =CRCI X Z6                                              0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                        0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                0.0

COMMENTS
    1979 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0        0.002340    0.0
    5250 KLYSTRONS WITHIN 9 DENSITY GRADIENTS.  ONE KLYSTRON POWER
    MODULE PER COST ELEMENT
```

```
                ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
   TABLE   1.1.9.1.27 P.T. KLYSTRON PHASE SHIFTERS

                  INPUT PARAMETERS                                     INPUT COEFFICIENTS

     T=       5250.00000       TF=         1.000000          CDCER=           0.0
     M=          1.000000     O&M=         0.0               CDEXP=           0.0
    CF=          1.200000      Z1=         1.000000          CICER=           0.001170
   PHI=          1.000000      Z2=        60.000000          CIEXP=           1.000000
     R=          0.0           Z3=         0.0               BYEAR=               1979
    DF=          1.000000      Z4=        60.000000     Z5=           0.0          Z6=          0.0

   CALCULATED VALUES       PM SET         SUM TO  1.1.9.1                          $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 0.0

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               0.001

 #RM =T / M                                                                     5250.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                                    1.000

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                    7.371


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3                0.0

 CIPS=CTB*Z4/Z2                                                                    0.0

     CRCI  =CTB  X R                                                               0.0
          PRE-IOC  CRCI =CRCI X Z6                                                 0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                           0.0

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                  0.0

 COMMENTS
     1979 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0        0.001170    0.0
     5250 KLYSTRON POWER MODULES.  ONE PHASE SHIFTER PER KLYSTRON SET.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.28 P. I. KLYSTRON PH. CONTROL ELECTRONICS

```
                 INPUT PARAMETERS                                  INPUT COEFFICIENTS

   T=      5250.00000     TF=         1.000000         CDCER=          0.0
   M=       184.000000    U&M=        0.0              CDEXP=          0.0
  CF=         1.200000    Z1=         1.000000         CICER=          0.000955
 PHI=         1.000000    Z2=        60.000000         CIEXP=          1.000000
   R=         0.0         Z3=         0.0              BYEAR=             1979
  DF=         1.000000    Z4=        60.000000    Z5=          0.0       Z6=          0.0

  CALCULATED VALUES      PM SET        SUM TO  1.1.9.1                          $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                  0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                0.211

#RM =T / M                                                                     28.533

E   =1.0 + LOG(PHI) / LOG(2.0)                                                  1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                     6.016


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               0.0

CTPS=CTB*Z4/Z2                                                                     0.0

   CRCI  =CTB  X R                                                                 0.0
         PRE-IOC  CRCI =CRCI X Z6                                                  0.0
         POST-IOC CRCI =CRCI X (1.0-Z6)                                            0.0

   CO&M  =U&M OR CTB*Z5/Z2/ENYR                                                    0.0

COMMENTS
   1979 DATA ENTERED FOR CDCER,CICER, AND U&M WERE     0.0        0.000955    0.0
   5250 KLYSTRON POWER MODULES.  ONE PHASE CONTROL ELECTRONICS PER
   184 KLYSTRONS
```

RUCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.29 P. T. KLYSTRON POWER DIVIDERS AND COMBINERS

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	5250.00000	TF=	1.000000			CDCER=	0.0
M=	184.000000	U&M=	0.0			CDEXP=	0.0
CF=	1.200000	Z1=	1.000000			CICER=	0.000152
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	0.0			BYEAR=	1979
DF=	1.000000	Z4=	60.000000	Z5=	0.0	Z6=	0.0

CALCULATED VALUES PM SET SUM TO 1.1.9.1 $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.034
#RM =T / M	28.533
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	0.958
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	0.0
CIPS=CTB*Z4/Z2	0.0
CRCI =CTR X R	0.0
PRE-IOC CRCI =CRCI X Z6	0.0
POST-IOC CRCI =CRCI X (1.0-Z6)	0.0
CU&M =U&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS
1979 DATA ENTERED FOR CDCER,CICER, AND U&M WERE 0.0 0.000152 0.0
5250 KLYSTRON POWER MODULES. ONE SET OF POWER DIVIDERS AND COMBINERS
PER 184 KLYSTRONS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.30 KLYSTRON SUBARRAY SYSTEM INTEGRATION

```
                INPUT PARAMETERS                                      INPUT COEFFICIENTS

     T=     5250.00000     TF=        1.000000          CDCER=          0.0
     M=       20.399994    O&M=       0.0               CDEXP=          0.0
    CF=        1.000000    Z1=        1.000000          CICER=          0.003986
   PHI=        1.000000    Z2=       60.000000          CIEXP=          1.000000
     R=        0.0         Z3=        0.0               BYEAR=             1979
    DF=        1.000000    Z4=       60.000000   Z5=          0.0          Z6=          0.0

   CALCULATED VALUES      PM SET        SUM TO  1.1.9.1                          $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                   0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                 0.081

#RM =T / M                                                                        257.353

E   =1.0 + LOG(PHI) / LOG(2.0)                                                      1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                     20.926

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3                  0.0

CIPS=CTB*Z4/Z2                                                                      0.0

    CRCI  =CIB  X R                                                                 0.0
          PRE-IOC  CRCI =CRCI X Z6                                                  0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                            0.0

    CO&M  =O&M OR CTR*Z5/Z2/ENYR                                                    0.0

COMMENTS
    1979 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0        0.003986    0.0
    SYSTEM INTEGRATION OF ITEMS 1.1.9.1.24 THROUGH 1.1.9.1.29.
    APPROXIMATELY 257 SUBARRAYS ON THE AVERAGE.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.31 PD&C - SW. GR. & REGULATORS - P.T.

```
                 INPUT PARAMETERS                                     INPUT COEFFICIENTS

   T=      11400.0000      TF=          1.000000          CDCER=          0.184860
   M=          9.000000    O&M=         0.0               CDEXP=          0.297000
  CF=          1.500000    Z1=          1.000000          CICER=          0.000468
 PHI=          1.000000    Z2=         60.000000          CIEXP=          1.000000
   R=          0.0         Z3=          0.0               BYEAR=              1979
  DF=          3.000000    Z4=         60.000000    Z5=          0.0          Z6=          0.0

   CALCULATED VALUES           KG         SUM TO  1.1.9.1                      $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                  6.159

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                0.006

*RM =T / M                                                                   1266.667

E   =1.0 + LOG(PHI) / LOG(2.0)                                                  1.000

CTFU=(CLRM / E)X((*RM X Z1+.5)XX(E) -0.5XX(E))                                     8.003


CIB =((CLRM/E)X((*RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3            0.0

CIPS=CTB*Z4/Z2                                                                     0.0

   CRCI  =CTB  X R                                                                 0.0
         PRE-IOC  CRCI =CRCI X Z6                                                  0.0
         POST-IOC CRCI =CRCI X (1.0-Z6)                                            0.0

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                    0.0

COMMENTS
   1979 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.184860    0.000468    0.0
```

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
    TABLE    1.1.9.1.32 PD&C - HI VOLTAGE CONVERT - P.T.

                  INPUT PARAMETERS                                      INPUT COEFFICIENTS

     T=      44500.0000      TF=          1.000000           CDCER=            0.184860
     M=          9.000000    O&M=         0.0                CDEXP=            0.297000
    CF=          1.500000    Z1=          1.000000           CICER=            0.000244
   PHI=          1.000000    Z2=         60.000000           CIEXP=            1.000000
     R=          0.0         Z3=          0.0                BYEAR=               1979
    DF=          2.000000    Z4=         60.000000     Z5=           0.0         Z6=          0.0

    CALCULATED VALUES            KG          SUM TO  1.1.9.1                     $,MILLIONS

  CD=CDCER X (1 X DF)XX(CDEXP) X CF                                                   8.183

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                 0.003

  #RM =T / M                                                                     4944.441

  E    =1.0 + LOG(PHI) / LOG(2.0)                                                   1.000

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                     16.287


  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                0.0

  CIPS=CTB*Z4/Z2                                                                      0.0

     CRCI   =CTB  X R                                                                 0.0
             PRE-IOC  CRCI =CRCI X Z6                                                 0.0
             POST-IOC CRCI =CRCI X (1.0-Z6)                                           0.0

     CO&M   =O&M OR CTB*Z5/Z2/ENYR                                                    0.0

  COMMENTS
     1979 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.184860    0.000244    0.0
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.33 PD&C - LU VOLTAGE CONVERT - P.T.

```
                 INPUT PARAMETERS                                   INPUT COEFFICIENTS

   T=      100.000000     TF=       1.000000           CDCER=          0.184860
   M=        9.000000     O&M=      0.0                CDEXP=          0.297000
  CF=        1.500000     Z1=       1.000000           CICER=          0.000468
 PHI=        1.000000     Z2=      60.000000           CIEXP=          1.000000
   R=        0.0          Z3=       0.0                RYEAR=              1979
  DF=        2.000000     Z4=      60.000000    Z5=        0.0          Z6=          0.0

  CALCULATED VALUES          KG          SUM TO  1.1.9.1                   $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                             1.338

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                           0.006

*RM =T / M                                                                 11.111

E   =1.0 + LOG(PHI) / LOG(2.0)                                              1.000

CTFU=(CLRM / E)X((*RM X Z1+.5)XX(E) -0.5XX(E))                                0.070


CTB =((CLRM/E)X((*RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3            0.0

CIPS=CTB*Z4/Z2                                                                0.0

    CRCI   =CTB  X R                                                          0.0
           PRE-IOC  CRCI =CRCI X Z6                                           0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                     0.0

    CO&M   =O&M OR CTB*Z5/Z2/ENYR                                             0.0

COMMENTS
    1979 DATA ENTERED FOR CDCER,CICER, AND O&M WERE    0.184860   0.000468   0.0
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.34 PD&C CONDUCTORS & INSULATION - P. T.

```
                 INPUT PARAMETERS                                          INPUT COEFFICIENTS

   T=      25800.0000      TF=          1.000000              CDCER=          0.184860
   M=          9.000000   O&M=          0.0                   CDEXP=          0.297000
  CF=          1.000000    Z1=          1.000000              CICER=          0.000005
 PHI=          1.000000    Z2=         60.000000              CIEXP=          1.000000
   R=          0.0         Z3=          0.0                   BYEAR=              1979
  DF=          1.000000    Z4=          0.0          Z5=            0.0           Z6=            0.0

   CALCULATED VALUES          K          SUM TO  1.1.9.1                            $,MILLIONS

CU=CDCER X (T X DF)XX(CDEXP) X CF                                                       3.777

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                     0.000

#RM =T / M                                                                          2866.667

E    =1.0 + LOG(PHI) / LOG(2.0)                                                        1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                          0.121


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))           ) / Z3                    0.0

CIPS=CTB*Z4/Z2                                                                          0.0

    CRCI  =CTB  X R                                                                     0.0
           PRE-IOC  CRCI =CRCI X Z6                                                     0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                               0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                        0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.158000    0.000004    0.0
```

```
              ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
      TABLE   1.1.9.1.35 BATTERIES - P.T. PRECURSOR

                     INPUT PARAMETERS                                    INPUT COEFFICIENTS

      T=      6400.00000      TF=       1.000000          CDCER=          0.040145
      M=        50.000000    O&M=       0.0               CDEXP=          0.734000
     CF=         1.500000     Z1=       1.000000          CICER=          0.030380
    PHI=         1.000000     Z2=      60.000000          CIEXP=          0.241000
      R=         0.0          Z3=       0.0               BYEAR=              1979
     DF=         0.800000     Z4=       0.0        Z5=           0.0         Z6=          0.0

     CALCULATED VALUES        KG          SUM TO  1.1.9.1                 $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                           31.793

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                          0.117

  #RM  =T / M                                                        128.000

  E    =1.0 + LOG(PHI) / LOG(2.0)                                      1.000

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                              14.974


  CTB  =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3        0.0

  CIPS=CTB*Z4/Z2                                                               0.0

      CRC1  =CTB   X R                                                         0.0
              PRE-IOC  CRCI =CRC1 X Z6                                         0.0
              POST-IOC CRCI =CRC1 X (1.0-Z6)                                   0.0

      CO&M  =O&M OR CTB*Z5/Z2/ENYR                                             0.0

  COMMENTS
      1978 DATA ENTERED FOR CDCER,CICER, AND O&M WERE    0.037000    0.028000    0.0
      50 KG PER CELL - SODIUM CHLORIDE FOR ANTENNA
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.36 P.T. - BATTERY PD&C

```
                    INPUT PARAMETERS                                        INPUT COEFFICIENTS

     T=      1600.00000     TF=        1.000000          CDCER=        0.057505
     M=       250.000000    U&M=       0.0               CDEXP=        0.890000
    CF=         1.000000    Z1=        1.000000          CICER=        0.013020
   PHI=         1.000000    Z2=       60.000000          CIEXP=        0.859000
     R=         0.0         Z3=        0.0               BYEAR=            1979
    DF=         0.100000    Z4=       60.000000   Z5=         0.0          Z6=          0.0

   CALCULATED VALUES        KG         SUM TO  1.1.9.1                         $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                              5.265

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                            1.494

 #RM =T / M                                                                 6.400

 E   =1.0 + LOG(PHI) / LOG(2.0)                                             1.000

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                 9.564


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3              0.0

 CIPS=CTB*Z4/Z2                                                                 0.0

     CRCI  =CTB  X R                                                            0.0
           PRE-IOC  CRCI =CRCI X Z6                                             0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                       0.0

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                               0.0

 COMMENTS
     1978 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.053000    0.012000    0.0
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.37 THERMAL CONTROL - INSULATION - PRECURSOR R.T.

```
                INPUT PARAMETERS                                      INPUT COEFFICIENTS

   T=     26400.0000      TF=        0.046043          CDCER=        0.182520
   M=         4.000000   O&M=        0.0               CDEXP=        0.511000
  CF=         1.000000    Z1=        1.000000          CICER=        0.118170
 PHI=         1.000000    Z2=       60.000000          CIEXP=        0.355000
   R=         0.0         Z3=        0.0               BYEAR=            1979
  DF=         1.000000    Z4=        0.0        Z5=          0.0     Z6=            0.0

   CALCULATED VALUES      KG         SUM TO  1.1.9.1                        $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                           33.170

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                          0.009

#RM =T / M                                                          6600.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                          1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                              58.742


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3           0.0

CIPS=CTB*Z4/Z2                                                               0.0

    CRCI  =CTB  X R                                                          0.0
          PRE-IOC  CRCI =CRCI X Z6                                           0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                     0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                             0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.156000    0.101000    0.0
```

```
                ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE    1.1.9.1.38 REFERENCE FREQUENCY GENERATOR - PRECURSOR

                INPUT PARAMETERS                                        INPUT COEFFICIENTS

     T=          1.000000     TF=        1.000000          CDCER=          0.585000
     M=          1.000000    O&M=        0.0               CDEXP=          1.000000
    CF=          1.000000     Z1=        1.000000          CICER=          0.117000
   PHI=          1.000000     Z2=       60.000000          CIEXP=          1.000000
     R=          0.0          Z3=        0.0               BYEAR=              1979
    DF=          1.000000     Z4=        0.0        Z5=          0.0       Z6=           0.0

    CALCULATED VALUES          SET          SUM TO   1.1.9.1                  $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                0.585

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                              0.117

#RM =T / M                                                                1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                            1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                   0.117


CTB =((CLRM/E)X((#RM X     Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3              0.0

CIPS=CTB*Z4/Z2                                                                   0.0

   CRCI  =CTB  X R                                                               0.0
         PRE-IOC  CRCI =CRCI X Z6                                                0.0
         POST-IOC CRCI =CRCI X (1.0-Z6)                                          0.0

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                  0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.500000    0.100000    0.0
   ENGINEERING ESTIMATE.  ONE SET PER SATELLITE PRECURSOR
```

```
          ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE   1.1.9.1.39 DIST. SYSTEM, COAXIAL CABLE

           INPUT PARAMETERS                                    INPUT COEFFICIENTS

   T=       8613.00000     TF=          1.000000          CDCER=          0.000035
   M=        261.000000    O&M=         0.0               CDEXP=          1.000000
  CF=          1.000000    Z1=          1.000000          CICER=          0.000070
 PHI=          1.000000    Z2=         60.000000          CIEXP=          1.000000
   R=          0.0         Z3=          0.0               BYEAR=              1979
  DF=          1.000000    Z4=          0.0        Z5=        0.0      Z6=            0.0

   CALCULATED VALUES          M          SUM TO  1.1.9.1                      $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                               0.302

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                             0.018

#RM =T / M                                                                  33.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                               1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                  0.605


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3             0.0

CIPS=CTR*Z4/Z2                                                                  0.0

    CRCI  =CTB  X R                                                             0.0
          PRE-IOC  CRCI =CRCI X Z6                                              0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                        0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE    0.000030    0.000060    0.0
    ENGINEERING ESTIMATE
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.40 DIST. SYSTEM DEVICES

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	100.000000	TF=	1.000000			CDCER=	0.000263		
M=	2.000000	O&M=	0.0			CDEXP=	1.000000		
CF=	1.000000	Z1=	1.000000			CICER=	0.005850		
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000		
R=	0.0	Z3=	0.0			BYEAR=	1979		
DF=	1.000000	Z4=	0.0	Z5=	0.0			Z6=	0.0

CALCULATED VALUES KG SUM TO 1.1.9.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.026
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.012
#RM =T / M	50.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.585
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
PRE-IOC CRCI =CRCI X Z6		0.0
POST-IOC CRCI =CRCI X (1.0-Z6)		0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.000225 0.005000 0.0
ENGINEERING ESTIMATE

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.41 P.T. - MASTER CONTROL COMPUTER - IMS/COM

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	1000.00000	TF=	1.000000			CDCER=	0.740610		
M=	500.000000	O&M=	0.0			CDEXP=	0.521000		
CF=	1.000000	Z1=	1.000000			CICER=	0.201240		
PHI=	1.000000	Z2=	60.000000			CIEXP=	0.535000		
R=	0.0	Z3=	0.0			BYEAR=	1979		
DF=	1.000000	Z4=	60.000000	Z5=	0.0			Z6=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			27.076
CLRM=CICER X (M)XX(CIEXP) X CF X TF			5.593
*RM =T / M		2.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((*RM X Z1+.5)XX(E) -0.5XX(E))			11.186
CTB =((CLRM/E)X((*RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRC1 =CTB X R			0.0
PRE-IOC CRC1 =CRC1 X Z6			0.0
POST-IOC CRC1 =CRC1 X (1.0-Z6)			0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.633000 0.172000 0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.42 P.T. BUS CONTROL UNIT

```
                 INPUT PARAMETERS                                INPUT COEFFICIENTS

    T=      170.000000     TF=        1.000000            CDCER=        0.119340
    M=        5.000000     O&M=       0.0                 CDEXP=        0.879000
   CF=        1.000000     Z1=        1.000000            CICER=        0.080730
  PHI=        1.000000     Z2=       60.000000            CIEXP=        0.557000
    R=        0.0          Z3=        0.0                 BYEAR=            1979
   DF=        1.000000     Z4=       60.000000     Z5=          0.0       Z6=          0.0

    CALCULATED VALUES           KG         SUM TO  1.1.9.1                      $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                              10.898

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                             0.198

 #RM =T / M                                                           34.000

 E    =1.0 + LOG(PHI) / LOG(2.0)                                        1.000

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                  6.727


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3            0.0

 CIPS=CTR*Z4/Z2                                                                  0.0

     CRCI   =CTB   X R                                                           0.0
            PRE-IOC  CRCI =CRCI X Z6                                             0.0
            POST-IOC CRCI =CRCI X (1.0-Z6)                                       0.0

     CO&M   =O&M OR CTB*Z5/Z2/ENYR                                               0.0

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.102000     0.069000     0.0
```

```
                  RUCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.1.9.1.43 P.T. - MICROPROCESSORS - IMS/COM

                      INPUT PARAMETERS                                    INPUT COEFFICIENTS

      T=          150.000000       TF=         1.000000          CDCER=          0.119340
      M=            5.000000      U&M=         0.0               CDEXP=          0.879000
     CF=            1.000000       Z1=         1.000000          CICER=          0.080730
    PHI=            1.000000       Z2=        60.000000          CIEXP=          0.557000
      R=            0.0            Z3=         0.0               RYEAR=              1979
     DF=            1.000000       Z4=        60.000000    Z5=         0.0          Z6=          0.0

     CALCULATED VALUES           KG         SUM TO  1.1.9.1                          $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                                   9.763

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                 0.198

  #RM =T / M                                                                  30.000

  E    =1.0 + LOG(PHI) / LOG(2.0)                                              1.000

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                      5.936


  CTB =((CLRM/E)X((#RM X     Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                0.0

  CIPS=CTB*Z4/Z2                                                                      0.0

      CRCI   =CTB   X R                                                               0.0
             PRE-IOC  CRCI =CRCI X Z6                                                 0.0
             POST-IOC CRCI =CRCI X (1.0-Z6)                                           0.0

      CO&M   =U&M OR CTB*Z5/Z2/ENYR                                                   0.0

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.102000    0.069000    0.0
                          0
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.44 P.T. - REMOTE ACQ & CONTROL - IMS/COM

```
                 INPUT PARAMETERS                                        INPUT COEFFICIENTS

   T=      190.000000    TF=        1.000000          CDCER=          0.119340
   M=        5.000000    O&M=       0.0               CDEXP=          0.879000
  CF=        1.000000    Z1=        1.000000          CICER=          0.080730
 PHI=        1.000000    Z2=       60.000000          CIEXP=          0.557000
   R=        0.0         Z3=        0.0               BYEAR=              1979
  DF=        0.100000    Z4=       60.000000    Z5=          0.0           Z6=          0.0

  CALCULATED VALUES          KG         SUM TO  1.1.9.1                      $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                              1.588

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                            0.198

#RM =T / M                                                             38.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                          1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                 7.519

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3              0.0

CIPS=CTB*Z4/Z2                                                                 0.0

    CRCI  =CTB  X R                                                            0.0
          PRE-IOC  CRCI =CRCI X Z6                                             0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                       0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                               0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE    0.102000   0.069000   0.0
```

RUCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.45 P.T. - SUBMULTIPLEXER - IMS/COM

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	3300.00000	TF=	1.000000			CDCER=	0.119340
M=	3.000000	U&M=	0.0			CDEXP=	0.879000
CF=	1.000000	Z1=	1.000000			CICER=	0.080730
PHI=	1.000000	Z2=	60.000000			CIEXP=	0.557000
R=	0.0	Z3=	0.0			BYEAR=	1979
DF=	0.020000	Z4=	60.000000	Z5=	0.0	Z6=	0.0

CALCULATED VALUES KG SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	4.744
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.149
#RM =T / M	1100.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	163.751
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	0.0
CIPS=CTB*Z4/Z2	0.0
CRCI =CTB X R	0.0
PRE-IOC CRCI =CRCI X Z6	0.0
POST-IOC CRCI =CRCI X (1.0-Z6)	0.0
CO&M =U&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE 0.102000 0.069000 0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.46 P.T. - INSTRUMENTATION - IMS/COM

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	10000.0000	TF=	1.000000			CDCER=	0.000117		
M=	0.074100	U&M=	0.0			CDEXP=	1.000000		
CF=	1.000000	Z1=	1.000000			CICER=	0.000468		
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000		
R=	0.0	Z3=	0.0			BYEAR=	1979		
DF=	1.000000	Z4=	60.000000	Z5=	0.0			Z6=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			1.170
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.000
*RM =T / M	134952.687		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((*RM X Z1+.5)XX(E) -0.5XX(E))			4.680
CTB =((CLRM/E)X((*RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.0
CO&M =U&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE 0.000100 0.000400 0.0

M = APPROX MASS PER SENSOR

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.1.47 P.T. - CABLES & HARNESS - IMS/COM

```
                 INPUT PARAMETERS                                  INPUT COEFFICIENTS

    T=     10600.0000     TF=        1.000000        CDCER=        0.277290
    M=       225.000000   O&M=       0.0             CDEXP=        0.297000
   CF=         1.000000   Z1=        1.000000        CICER=        0.000070
  PHI=         1.000000   Z2=       60.000000        CIEXP=        1.000000
    R=         0.0        Z3=        0.0             BYEAR=        1979
   DF=         1.000000   Z4=       60.000000   Z5=        0.0     Z6=          0.0

   CALCULATED VALUES        KG        SUM TO  1.1.9.1                       $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                            4.350

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                          0.016

#RM =T / M                                                               47.111

E   =1.0 + LOG(PHI) / LOG(2.0)                                            1.000

CIFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                               0.744


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(F))        ) / Z3            0.0

CIPS=CTB*Z4/Z2                                                               0.0

   CRCI  =CTB  X R                                                           0.0
         PRE-IOC  CRCI =CRCI X Z6                                            0.0
         POST-IOC CRCI =CRCI X (1.0-Z6)                                      0.0

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                              0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE    0.237000    0.000060    0.0
```

```
              ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.1.9.1.48 P.T. TRACKS AND ACCESSWAYS FOR MW ANT

                    INPUT PARAMETERS                                INPUT COEFFICIENTS

     T=        12000.0000     TF=        1.000000        CDCER=          0.026910
     M=         1000.00000    U&M=       0.0             CDEXP=          0.800000
    CF=            1.000000   Z1=        1.000000        CICER=          0.000058
   PHI=            1.000000   Z2=       60.000000        CIEXP=          1.000000
     R=            0.0        Z3=        0.0             BYEAR=              1979
    DF=            0.500000   Z4=       60.000000   Z5=          0.0      Z6=            0.0

     CALCULATED VALUES        KG        SUM TO  1.1.9.1                  $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                        28.342

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                       0.059

  #RM =T / M                                                           12.000

  E   =1.0 + LOG(PHI) / LOG(2.0)                                        1.000

  CIFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                            0.702


  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3        0.0

  CIPS=CTB*Z4/Z2                                                            0.0

      CRCI  =CTB  X R                                                       0.0
           PRE-IOC  CRCI =CRCI X Z6                                         0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                   0.0

      CO&M  =U&M OR CTB*Z5/Z2/ENYR                                          0.0

  COMMENTS
      1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.023000    0.000050    0.0
      MEMBERS AT ANTENNA FOR INSTALLATION, C/O, & VERIFICATION
      OF 5250 POWER MODULES
```

```
              ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
    TABLE   1.1.9.1.49 P.T. ANT. MW LIFTS - INSTALL & C/O EQUIP.

                  INPUT PARAMETERS                               INPUT COEFFICIENTS

      T=       15000.0000      TF=          1.000000          CDCER=          0.182520
      M=        1000.00000     U&M=         0.0               CDEXP=          0.511000
     CF=           1.500000    Z1=          1.000000          CICER=          0.118170
    PHI=           1.000000    Z2=         60.000000          CIEXP=          0.355000
      R=           0.0         Z3=          0.0               BYEAR=              1979
     DF=           1.000000    Z4=         60.000000    Z5=          0.0          Z6=          0.0

    CALCULATED VALUES           KG        SUM TO  1.1.9.1                         $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                                  37.272

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                 2.059

 #RM =T / M                                                                15.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                             1.000

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                     30.881


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                 0.0

 CIPS=CTB*Z4/Z2                                                                      0.0

     CRCI  =CTB  X R                                                                 0.0
           PRE-IOC  CRCI =CRCI X Z6                                                  0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                            0.0

     CU&M  =U&M OR CTB*Z5/Z2/ENYR                                                    0.0

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE      0.156000    0.101000    0.0
     CONVEYORS, POSITIONING STRUCTURES, INSTALLATION AND C/O EQUIPMENT TO
              SUPPORT ANTENNA POWER MODULE ASSEMBLY
```

```
                ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
   TABLE    1.1.9.2.1   PRECURSOR STS TRANSPORTATION

                  INPUT PARAMETERS                                INPUT COEFFICIENTS

   T=          119.000000      IF=          1.000000       CDCER=          0.0
   M=            1.000000      O&M=         0.0            CDEXP=          0.0
   CF=           1.000000      Z1=          1.000000       CICER=         27.000076
   PHI=          1.000000      Z2=         60.000000       CIEXP=          1.000000
   R=            0.0           Z3=          0.0            BYEAR=             1979
   DF=           1.000000      Z4=         60.000000   Z5=          0.0       Z6=        0.0

   CALCULATED VALUES        FLIGHT          SUM TO  1.1.9.2                 $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                           0.0

 CLRM=CICER X (M)XX(CIEXP) X CF X IF                                        27.000

 #RM =T / M                                                              119.000

 E    =1.0 + LOG(PHI) / LOG(2.0)                                           1.000

 CIFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                           3213.010


 CTB =((CLRM/E)X((#RM X     Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3        0.0

 CIPS=CTB*Z4/Z2                                                              0.0

     CRCI  =CTB  X R                                                         0.0
             PRE-IOC  CRCI =CRCI X Z6                                        0.0
             POST-IOC CRCI =CRCI X (1.0-Z6)                                  0.0

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                            0.0

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0        23.076996     0.0
     $27 MILLION  PER STS RT FLIGHT TO SUPPORT PRECURSOR ACTIVITY(79 DOLLARS)
     INCLUDING VEHICLES. 6 PERSONNEL FLIGHTS & 113 CARGO FLIGHTS.
```

```
            ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.1.9.2.2   PRECURSOR CONSTRUCTION CREW

                  INPUT PARAMETERS                                     INPUT COEFFICIENTS

      T=         90.000000     TF=        1.000000        CDCER=         0.0
      M=         90.000000    U&M=        0.0             CDEXP=         0.0
     CF=          1.000000     Z1=        1.000000        CICER=         0.073008
    PHI=          1.000000     Z2=       60.000000        CIEXP=         1.000000
      R=          0.0          Z3=        0.0             BYEAR=             1979
     DF=          1.000000     Z4=       60.000000     Z5=          0.0        Z6=          0.0

     CALCULATED VALUES         CREW         SUM TO  1.1.9.2                    $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                              0.0

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                            6.571

  *RM =T / M                                                                1.000

  E   =1.0 + LOG(PHI) / LOG(2.0)                                            1.000

  CTFU=(CLRM / E)X((*RM X  Z1+.5)XX(E) -0.5XX(E))                               6.571


  CTB =((CLRM/E)X((*RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3            0.0

  CIPS=CTR*Z4/Z2                                                                0.0

     CRCI  =CTB  X R                                                            0.0
          PRE-IOC  CRCI =CRCI X Z6                                              0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                        0.0

     CO&M  =U&M OR CTB*Z5/Z2/ENYR                                               0.0

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE      0.0        0.062400    0.0
     AVERAGE PRECURSOR CREW OF 90 MEN DURING 12 MONTH LEO CONSTRUCTION
     ACTIVITY
```

```
              ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
   TABLE    1.1.9.2.3   PRECURSOR GEO TEST ACTIVITY

                  INPUT PARAMETERS                                   INPUT COEFFICIENTS

      T=          20.000000     TF=          1.000000          CDCER=         0.0
      M=          20.000000    O&M=          0.0               CDEXP=         0.0
     CF=           1.000000     Z1=          1.000000          CICER=         0.029999
    PHI=           1.000000     Z2=         60.000000          CIEXP=         1.000000
      R=           0.0          Z3=          0.0               BYEAR=            1979
     DF=           1.000000     Z4=         60.000000     Z5=          0.0       Z6=          0.0

    CALCULATED VALUES     GRD.CREW          SUM TO   1.1.9.2                        $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                                     0.0

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                   0.600

 #RM =T / M                                                                        1.000

 E    =1.0 + LOG(PHI) / LOG(2.0)                                                   1.000

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                        0.600

 CTB =((CLRM/E)X((#RM X     Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                  0.0

 CIPS=CTP*Z4/Z2                                                                        0.0

    CRCI   =CTB   X R                                                                  0.0
           PRE-IOC  CRCI =CRCI X Z6                                                    0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                              0.0

    COGM   =O&M OR CTB*Z5/Z2/ENYR                                                      0.0

 COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0         0.025640    0.0
    MANPOWER REQUIREMENTS FOR AVERAGE 6 MONTH PRECURSOR GROUND TEST AND
    OPERATIONS ACTIVITY WITH PRECURSOR AT GEO.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.1.9.2.4 PRECURSOR PROPELLANT

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	1.000000	TF=	1.000000			CDCER=	0.0		
M=	1.000000	O&M=	0.0			CDEXP=	0.0		
CF=	1.000000	Z1=	1.000000			CICER=	1.010880		
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000		
R=	0.0	Z3=	0.0			BYEAR=	1979		
DF=	1.000000	Z4=	60.000000	Z5=	0.0		Z6=	0.0	

CALCULATED VALUES	KG	SUM TO 1.1.9.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.011
*RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			1.000
CTFU=(CLRM / E)X((*RM X Z1+.5)XX(E) -0.5XX(E))			1.011
CTB =((CLRM/E)X((*RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.0 0.864000 0.0
OPERATIONS AND TEST PROPELLANT ($1/KG-1977)=$1.17/KG AT 864000 KG
PRECURSOR REQUIREMENT.

1.1.9.3 GROUND RECEIVING FACILITY

This element covers a ground receiving facility for microwave power reception during test and operational phases of the proof-of-concept/test article program.

Figure 1.1-11 illustrates a typical concept for the ground receiving facility. It is about the size of one-half the area of a football field. Rectenna panels are comprised of dipoles, appropriately spaced, on a ground plane of wire mesh builder's "cloth."

An engineering estimate is presented in Table 1.1.9.3 considering that DDT&E for this facility is included in the research and development program.

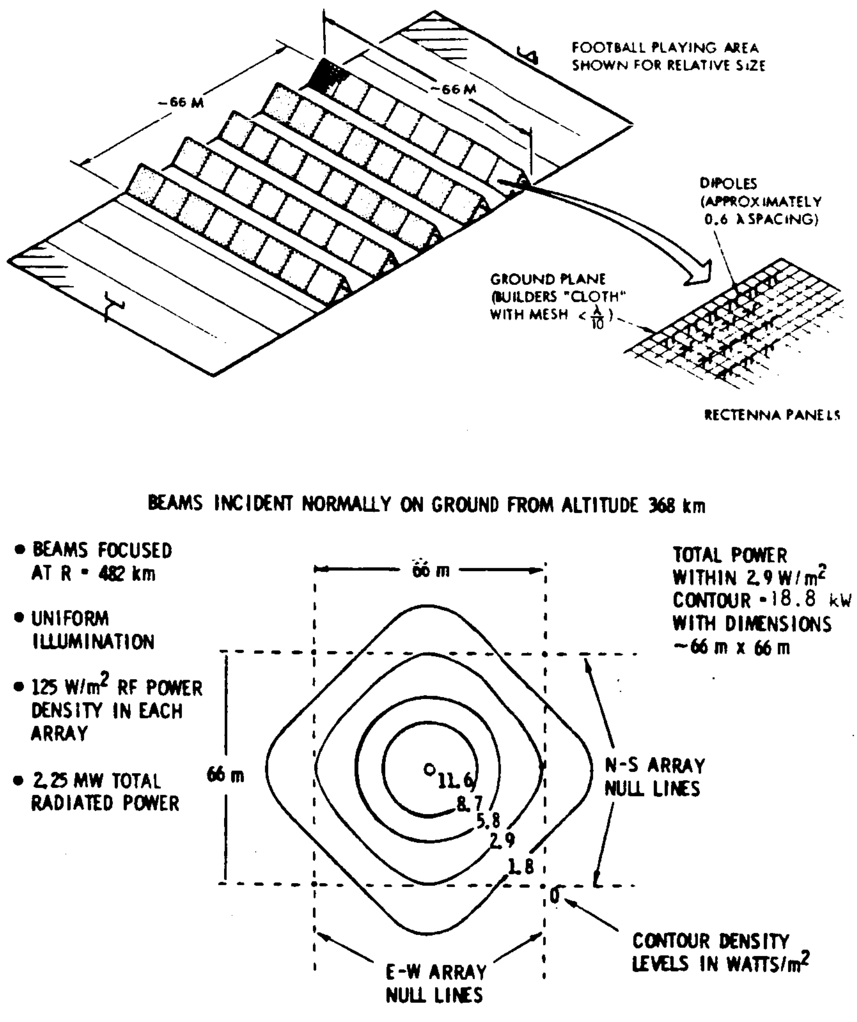


Figure 1.1-11. Ground Receiving Facility

```
                 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.1.9.3     PRECURSOR GROUND RECEIVING FACILITY

                 INPUT PARAMETERS                                        INPUT COEFFICIENTS

     T=          1.000000     TF=       1.000000             CDCER=         0.0
     M=          1.000000     O&M=      0.0                  CDEXP=         0.0
    CF=          1.000000     Z1=       1.000000             CICER=         4.999995
   PHI=          1.000000     Z2=      60.000000             CIEXP=         1.000000
     R=          0.0          Z3=       0.0                  BYEAR=             1979
    DF=          1.000000     Z4=      60.000000      Z5=          0.0      Z6=           0.0

     CALCULATED VALUES     FACILITY           SUM TO  1.1.9                           $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                                      0.0

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                    5.000

  #RM =T / M                                                                          1.000

  E    =1.0 + LOG(PHI) / LOG(2.0)                                                     1.000

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                         5.000


  CTH =((CLRM/E)X((#RM X     Z3 + 0.5)XX(E) -0.5XX(E))            ) / Z3                 0.0

  CIPS=CTB*Z4/Z2                                                                         0.0

     CRC1   =CTB   X R                                                                   0.0
            PRE-IOC  CRC1 =CRC1 X Z6                                                     0.0
            POST-IOC CRC1 =CRC1 X (1.0-Z6)                                               0.0

     CO&M   =O&M OR CTB*Z5/Z2/ENYR                                                       0.0

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE       0.0        4.273500     0.0
     ENGINEERING ESTIMATE.  DDT&E FOR PRECURSOR RECTENNA INCLUDED IN GBED
     PROGRAM
```

1.2 SPACE CONSTRUCTION AND SUPPORT

This element includes all hardware and activities/operations required to fabricate, assemble, checkout, operate and maintain the satellite system and supporting elements of the space segment. Included are logistic support facilities and operations, construction base and operations, and operations/maintenance requirements.

The updated Rockwell SPS Reference Configuration—1980 is used as the baseline concept for development of cost and programmatic information. As indicated in previous sections, four other concepts were studied and defined for purposes of establishing cost estimates including those of required construction and support equipment unique to these particular designs. A summary of cost estimates for these configurations is presented in Table 1.2-1.

Table 1.2-1. Investment Costs for Space Construction and Support Equipment

SPS SATELLITE CONCEPT (1980)	1979 DOLLARS × 10^6			
	SPS OPTION QUANTITY	INVESTMENT PER SATELLITE	RCI/O&M PER SAT. YR.	
			PRE-IOC	POST-IOC
ROCKWELL SPS CR-2 REFERENCE CONFIGURATION (3-TROUGH/PLANAR/KLYSTRON) SATELLITE MASS (DRY)—25.306×10^6 kg	60	$209.874	$ 8.044	$ 30.762
SPS CR-2 MAGNETRON CONFIGURATION (3-TROUGH/PLANAR) SATELLITE MASS (DRY)—21.44×10^6 kg	54	225.611	10.453	31.170
DUAL END-MOUNTED ANTENNA CR-2 SPS (3-TROUGH/PLANAR/SOLID STATE) SATELLITE MASS (DRY)—31.978×10^6 kg	58	214.741	8.325	31.098
SOLID-STATE SANDWICH CONFIGURATION CR-5 (DUAL ANTENNA AND REFLECTORS—GaAs) SATELLITE MASS (DRY)—16.423×10^6 kg	125	107.426	6.080	25.523
SOLID-STATE SANDWICH CONFIGURATION CR-5 (DUAL ANTENNA AND REFLECTORS—MBG) SATELLITE MASS (DRY)—13.109×10^6 kg	98	137.024	7.120	26.503

An overall scenario of construction sequences leading to the first operational SPS satellite is shown in Figure 1.2-1. The initial step is to establish a LEO Station for the fabrication of a construction fixture to build the SCB. Crew and materials would be transported to LEO by the STS HLLV with liquid rocket boosters. Cost estimates on the STS growth vehicle for personnel and a derivative vehicle for cargo are presented in Section 1.3.3. Shuttle external tanks from the use of these vehicles would be delivered to LEO and combined to form a construction fixture for the SCB.

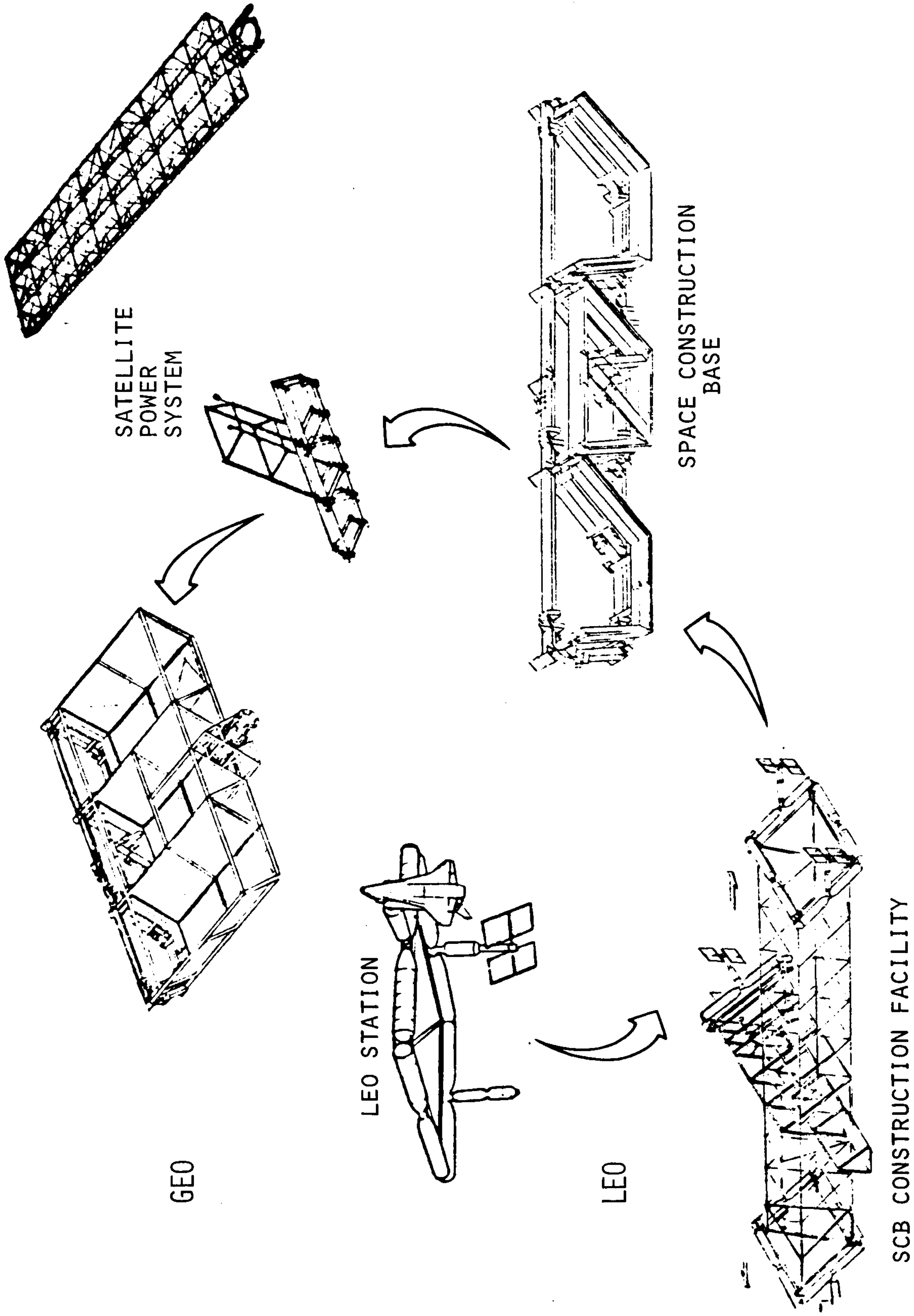


Figure 1.2-1. Satellite Construction

After SCB construction, one of its first functional requirements would be to fabricate EOTV's that will serve as the vehicle for LEO-GEO cargo transfer and the movement of this base to its operational location in GEO. Once in GEO, the SCB would be outfitted for construction of a first satellite. As the SPS-HLLV is scheduled for availability when the SCB is completed, this vehicle would be used to deliver masses to LEO for EOTV and SPS satellite construction. During the 30 year satellite construction period, the SPS-HLLV will become the transportation element for delivering construction mass and personnel to LEO.

The energy conversion segment of the satellite structure is constructed by the integrated SCB in a single pass. Satellite longerons of a length sufficient to connect the triangular frames of the slip ring support structure are fabricated, followed by construction of the slip ring interface structure, and the first satellite structure frame. The SCB then proceeds to fabricate/install the remainder of the satellite structure and solar converter. Construction of the slip rings, and yoke (interface) takes place concurrently using free flying fabrication facilities to support this building process (Figure 1.2-2).

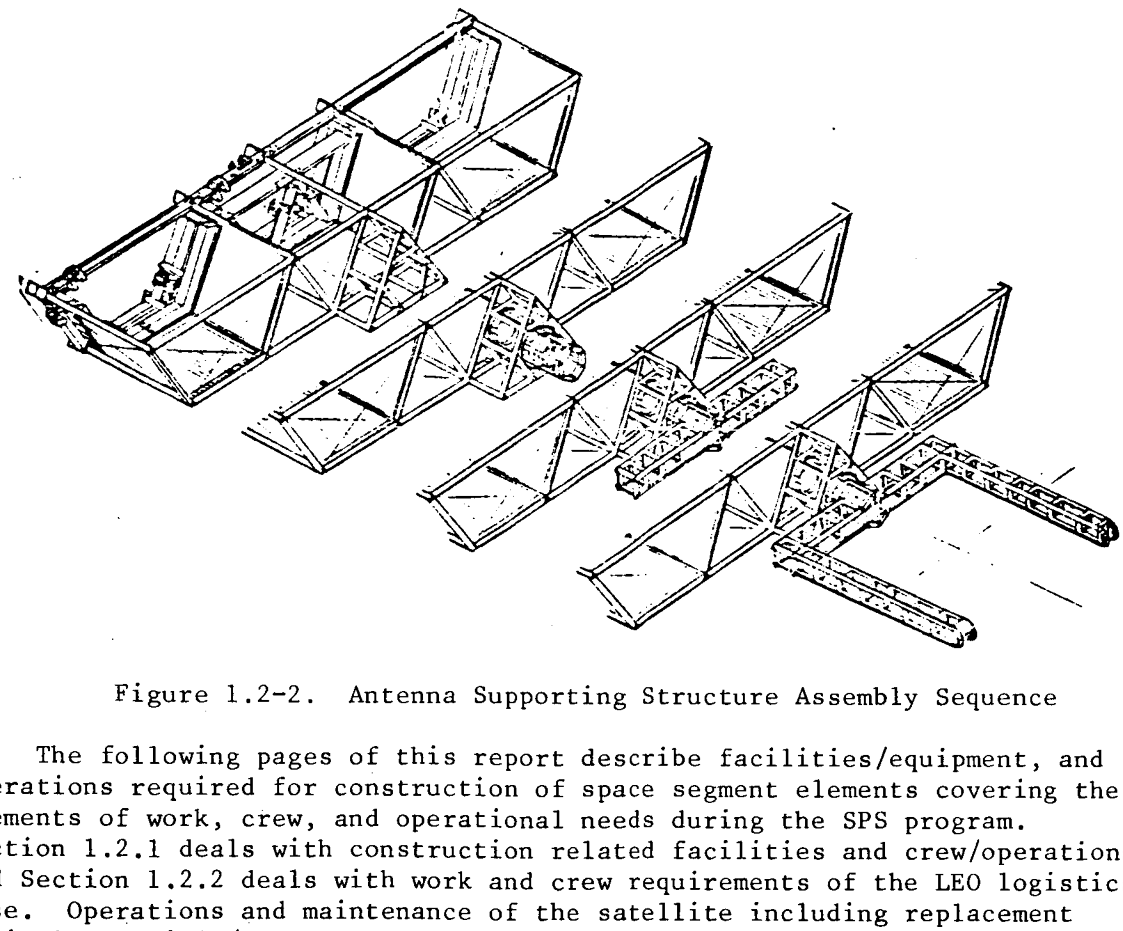


Figure 1.2-2. Antenna Supporting Structure Assembly Sequence

The following pages of this report describe facilities/equipment, and operations required for construction of space segment elements covering the elements of work, crew, and operational needs during the SPS program. Section 1.2.1 deals with construction related facilities and crew/operations; and Section 1.2.2 deals with work and crew requirements of the LEO logistics base. Operations and maintenance of the satellite including replacement capital materials/systems, after SPS-IOC, is included in Section 1.2.3.

1.2.1 CONSTRUCTION FACILITIES

This element includes the facilities, equipment, and operations required to fabricate, assemble, and checkout the satellite system. Specifically included are crew support facilities, the SCB and central control facility, fabrication and assembly equipment/facilities, cargo depots, and crew/provisions during construction.

Satellites are constructed in GEO at its designated longitudinal location. The SCB supports construction of two satellites per year during the program and serves as headquarters for operations and maintenance activities necessary to support the satellite.

The SCB is constructed of composites and consists of the fabrication fixture, construction equipment, and base support facilities. It is in the form of three troughs, corresponding to the satellite configuration and permits simultaneous construction of all troughs. Additional structural members are located in the middle trough to support fabrication of rotary joint and antenna structures. Figure 1.2-3 illustrates the construction base and shows the location of work and crew facilities.

SCB fabrication fixture assembly and support equipment, and crew/work modules are itemized in Table 1.2-2. Modules used to support crew/work activities are of various internal configurations to accommodate specific functional requirements. All modules are of the same diameter and most are of the same length, their dimensions and mass being in compliance with space transportation system constraints. Modules are located on the fab fixture along with SCB assembly and support equipment.

The Airlock Docking Module (ADM) is used to join other base modules to provide docking accommodations for other elements such as crew transport modules, consumables logistics modules (CLM) and intra-base logistics vehicles, and for transfer of opersonnel and equipment between different pressure environments. The Crew Habitability Module (CHM) provides stateroom and personal hygiene facilities, and support systems for 24 to 30 crew members. The Base Management Module (BMM) houses operational communications and control systems for the base. Power Modules (PM) are photovoltaic power systems (collectors, converters, conditioners, and storage) which support all base power requirements. Pressurized Storage Modules (PSM) provide an area for storage and workshop accommodations. Shielding (SHD) is provided in selected modules to protect against solar flare radiation. A Crew Support Module (CSM) provides the galley, recreational and medical facilities and support subsystems.

1.2.1.1 WORK SUPPORT FACILITIES—SCB

This element includes work facilities and equipment required for satellite fabrication, assembly, and checkout. Included are beam fabricators, manipulators, assembly jigs, installation and deployment equipment, and cargo storage depots. Excluded are the facilities related to crew support.

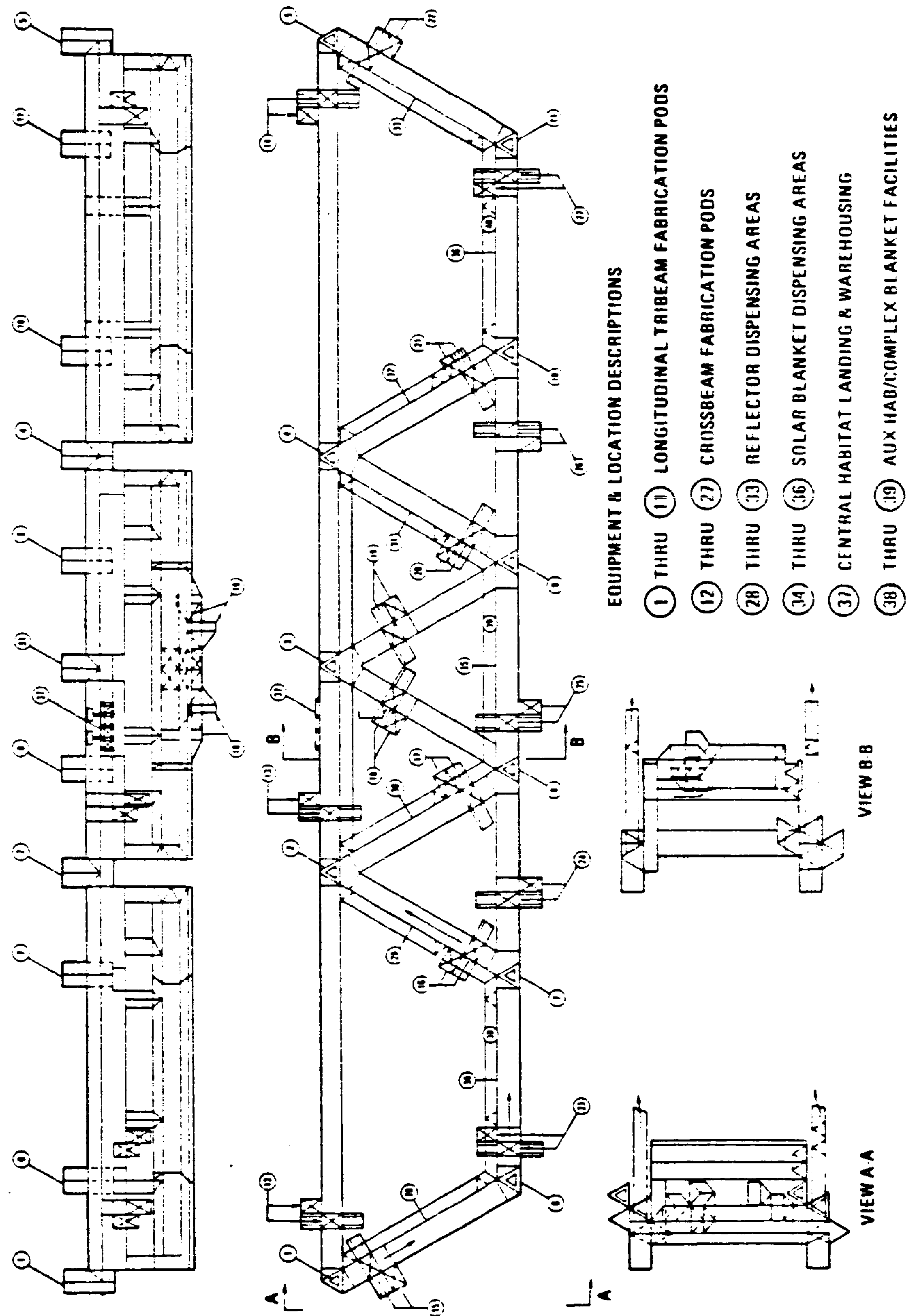


Figure 1.2-3. Satellite Construction Base (SCB)

Table 1.2-2. Construction Facilities

SYSTEM DESCRIPTION	QUANTITY FOR CONSTRUCTION
WORK SUPPORT FACILITIES (1.2.1.1)	
BEAM MACHINE	198
BEAM MACHINE CASSETTES	1206
CABLE ATTACHMENT MACHINES	78
REMOTE MANIPULATOR	55
SOLAR BLANKET DISPENSER MACHINE	78
SOLAR BLANKET CASSETTES	1560
REFLECTOR DISPENSER MACHINES	6
REFLECTOR CASSETTES	120
CABLE/CATENARY DISPENSERS	84
ANTENNA PANEL INSTALLATION EQUIPMENT	1
GANTRY/CRANES	12
CARGO STORAGE DEPOT	4
SCB FABRICATION FIXTURE	1
AIRLOCK DOCKING MODULE	17
BASE MANAGEMENT MODULE	4
POWER MODULE	4
PRESSURIZED STORAGE MODULE	4
CREW SUPPORT FACILITIES (1.2.1.2)	
AIRLOCK DOCKING MODULE	5
CREW HABITABILITY MODULE	17
CONSUMABLES LOGISTICS MODULE	9
SHIELDING	8
CREW SUPPORT MODULE	3

Modules associated with work support activities include the ADM-17 units, BMM-4 modules, PM-4 units, and PSM-4 modules. CER's used for these modules were based on Rockwell Space Station studies.

All SPS unique fabrication/orbital construction assembly and support equipment is included in this section (reference Table 1.2-2). Included are the tri-beam fabricators, cable attachment machines, solar blanket/concentrator dispensing machines, and antenna panel installation equipment. Each of these requirements were analyzed for equipment usage, replacement factors, O&M, and projected costs based on engineering estimates of design characteristics. The items of assembly and support equipment and base modules remain on the SCB as it transfers from one construction site to another.

1.2.1.2 CREW SUPPORT FACILITIES - SCB

This element includes facilities and equipment required for life support and well-being of the crew members. Included are living quarters, central control facilities, recreation facilities, and health facilities of the satellite construction base. Crew support facilities include 5 ADMs, 17 CHMs, 9 CLMs, 8 shielding and 3 CSMs.

1.2.1.3 OPERATIONS

This element includes the planning, development, and conduct of operations at the construction facility. It includes both direct and support personnel and expendable maintenance supplies for satellite assembly and checkout.

This element has been divided into the subelements of operations and consumables where an average crew of 317 persons per shift is required to man the SCB over the normal six month fabrication period. A crew rotation is scheduled for every three months. Consumables for the SCB are calculated at 3.6 kg/person/day.

1.2.1.4 COST ESTIMATES

Cost estimates for work and crew facilities, plus operations, are referenced in Table 1.2-3.

Table 1.2-3. Construction Facility Estimates

WBS TABLE NO's	DESCRIPTION
1.2.1.1.1 thru 1.2.1.1.17	Work Support Facilities—SCB
1.2.1.2.1 thru 1.2.1.2.5	Crew Support Facilities—SCB
1.2.1.3.1, 1.2.1.3.2	SCB Operations

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.2.1.1.1   BEAM MACHINE

               INPUT PARAMETERS                                    INPUT COEFFICIENTS

     T=          1.000000      TF=        1.000000          CDCER=          2.340000
     M=          1.000000     O&M=        0.810810          CDEXP=          1.000000
    CF=          1.000000      Z1=      198.000000          CICER=          0.819000
   PHI=          0.950000      Z2=       60.000000          CIEXP=          1.000000
     R=          0.0           Z3=      198.000000          BYEAR=              1979
    DF=          1.000000      Z4=      198.000000    Z5=          0.0           Z6=          1.000000

     CALCULATED VALUES         SET        SUM TO  1.2.1.1                      $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                             2.340

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                           0.819

  *RM =T / M                                                                 1.000

  E   =1.0 + LOG(PHI) / LOG(2.0)                                             0.926

  CTFU=(CLRM / E)X((*RM X Z1+.5)XX(E) -0.5XX(E))                                118.220


  CTB =((CLRM/E)X((*RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3           0.597

  CIPS=CTB*Z4/Z2                                                                1.970

     CRCI  =CTB  X R                                                            0.0
           PRE-IOC  CRCI =CRCI X Z6                                             0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                       0.0

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                               0.811

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      2.000000    0.700000    0.693000
     2 METER BEAM MACHINES.  COSTS BASED ON NAS9-15310. 30 YEAR LIFE
     ESTABLISHED WITH MAINTENANCE AGAINST A 3 YEAR FUL TIME SERVICE/DUTY
     CYCLE
```

```
            ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE   1.2.1.1.2  BEAM MACHINE CASSETTES SET

               INPUT PARAMETERS                                    INPUT COEFFICIENTS

     T=          1.000000     TF=        1.000000          CDCER=          0.936000
     M=          1.000000     U&M=       0.115704          CDEXP=          1.000000
    CF=          1.000000     Z1=     1206.00000           CICER=          0.009594
   PHI=          0.950000     Z2=       60.000000          CIEXP=          1.000000
     R=          0.666670     Z3=     3618.00000           BYEAR=              1979
    DF=          1.000000     Z4=     2412.00000     Z5=           0.0         Z6=          1.000000

     CALCULATED VALUES       SET        SUM TO  1.2.1.1                       $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                              0.936

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                            0.010

 #RM =T / M                                                                 1.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                             0.926

 CIFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                 7.389


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3             0.006

 CIPS=CTB*Z4/Z2                                                                 0.227

    CRCI  =CTB  X R                                                             0.004
          PRE-IOC  CRCI =CRCI X Z6                                              0.004
          POST-IOC CRCI =CRCI X (1.0-Z6)                                        0.0

    CO&M  =U&M OR CTB*Z5/Z2/ENYR                                                0.116

 COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE      0.800000   0.008200   0.098892
    SERVICE/DUTY CYCLE OF 3 YEARS WITH REPLACEMENT EVERY 15 YEARS.
    1206 FOR RCI.  Z4=1206 SCB REQUIREMENT PLUS 1206 ROTATION
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.1.1.3 CABLE ATTACHMENT MACHINE

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000			CDCER=	5.031000
M=	1.000000	O&M=	0.228150			CDEXP=	1.000000
CF=	1.000000	Z1=	78.000000			CICER=	0.585000
PHI=	0.950000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	78.000000			BYEAR=	1979
DF=	1.000000	Z4=	78.000000	Z5=	0.0	Z6=	1.000000

CALCULATED VALUES SET SUM TO 1.2.1.1		$,MILLIONS
CD=CDCER X (1 X DF)XX(CDEXP) X CF		5.031
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.585
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		35.576
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.456
CIPS=CTB*Z4/Z2		0.593
CRC1 =CTB X R		0.0
PRE-IOC CRC1 =CRC1 X Z6		0.0
POST-IOC CRC1 =CRC1 X (1.0-Z6)		0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR		0.228

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 4.300000 0.500000 0.195000

SERVICE/DUTY CYCLE OF 3 YEARS WITH 30 YEAR EQUIPMENT LIFE TIME

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.2.1.1.4  REMOTE MANIPULATOR

                    INPUT PARAMETERS                                     INPUT COEFFICIENTS

     T=          1.000000    TF=         1.000000        CDCER=          8.049601
     M=          1.000000    O&M=        0.360250        CDEXP=          1.000000
     CF=         1.000000    Z1=        55.000000        CICER=          1.310049
   PHI=          0.980000    Z2=        60.000000        CIEXP=          1.000000
     R=          0.030600    Z3=       110.000000        BYEAR=              1979
    DF=          0.500000    Z4=        55.000000   Z5=          0.0         Z6=          1.000000

     CALCULATED VALUES       SET         SUM TO  1.2.1.1                     $,MILLIONS

  CU=CDCER X (T X DF)XX(CDEXP) X CF                                             4.025

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                           1.310

  #RM =T / M                                                                1.000

  E   =1.0 + LOG(PHI) / LOG(2.0)                                            0.971

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                               65.929


  CTB =((CLRM/E)X((#RM X     Z3 + 0.5)XX(E) -0.5XX(E))       ) / Z3            1.176

  CIPS=CTB*Z4/Z2                                                                1.078

     CRC1  =CTB  X R                                                            0.036
           PRE-IOC  CRCI =CRC1 X Z6                                             0.036
           POST-IOC CRCI =CRC1 X (1.0-Z6)                                       0.0

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                               0.360

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     6.880000   1.119700   0.307906
     SERVICE/DUTY CYCLE OF 7.5 YEARS WITH LIFE AT 15 YEARS FOR RC1.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.1.1.5 BLANKET DISPENSER MACHINE

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	1.000000	TF=	1.000000			CDCER=	4.680000		
M=	1.000000	O&M=	0.182520			CDEXP=	1.000000		
CF=	1.000000	Z1=	78.000000			CICER=	0.468000		
PHI=	0.960000	Z2=	60.000000			CIEXP=	1.000000		
R=	0.0	Z3=	78.000000			BYEAR=	1979		
DF=	1.000000	Z4=	78.000000	Z5=	0.0			Z6=	1.000000

CALCULATED VALUES SET SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	4.680
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.468
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	33.076
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	0.424
CIPS=CTB*Z4/Z2	0.551
CRCI =CTB X R	0.0
PRE-IOC CRCI =CRCI X Z6	0.0
POST-IOC CRCI =CRCI X (1.0-Z6)	0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR	0.183

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 4.000000 0.400000 0.156000

SERVICE/DUTY CYCLE OF 2.5 YEARS WITH 30 YEAR LIFE FOR RCI

```
              ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
   TABLE   1.2.1.1.6   SOLAR BLANKET CASSETTES

                  INPUT PARAMETERS                              INPUT COEFFICIENTS

     T=        1.000000      TF=        1.000000        CDCER=         0.936000
     M=        1.000000     U&M=        0.156000        CDEXP=         1.000000
    CF=        1.250000      Z1=     1560.00000         CICER=         0.011700
   PHI=        1.000000      Z2=       60.000000        CIEXP=         1.000000
     R=        1.733330      Z3=     6240.00000         BYEAR=             1979
    DF=        1.000000      Z4=     3120.00000    Z5=          0.0     Z6=         1.000000

   CALCULATED VALUES        SET          SUM TO  1.2.1.1                        $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 1.170

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               0.015

 #RM =T / M                                                                1.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                            1.000

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                    22.815

 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3                  0.015

 CIPS=CTB*Z4/Z2                                                                    0.761

    CRC1  =CTB  X R                                                                0.025
          PRE-IOC  CRCI =CRC1 X Z6                                                 0.025
          POST-IOC CRCI =CRC1 X (1.0-Z6)                                           0.0

    CO&M  =U&M OR CTB*Z5/Z2/ENYR                                                   0.156

 COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE      0.800000    0.010000    0.133333
    SERVICE/DUTY CYCLE AT 2.5 YEARS WITH 10 YEAR LIFE.  3120 FOR RCI.
    Z4=1560 FOR SCB AND 1560 FOR ROTATION
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.1.1.7 REFLECTOR DISPENSER MACHINE

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000			CDCER=	7.020000
M=	1.000000	O&M=	0.028080			CDEXP=	1.000000
CF=	1.000000	Z1=	6.000000			CICER=	0.936000
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	6.000000			BYEAR=	1979
DF=	1.000000	Z4=	6.000000	Z5=	0.0	Z6=	1.000000

CALCULATED VALUES SET SUM TO 1.2.1.1 $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF		7.020
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.936
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		5.442
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.907
CIPS=CTB*Z4/Z2		0.091
CRCI =CTB X R		0.0
PRE-IOC CRCI =CRCI X Z6		0.0
POST-IOC CRCI =CRCI X (1.0-Z6)		0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR		0.028

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 6.000000 0.800000 0.024000

SERVICE/DUTY CYCLE AT 2.5 YEARS WITH 30 YEAR LIFE.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.1.1.8 REFLECTOR CASSETTES

```
                        INPUT PARAMETERS                                   INPUT COEFFICIENTS

     T=          1.000000    TF=         1.000000        CDCER=          1.170000
     M=          1.000000    O&M=        0.042120        CDEXP=          1.000000
    CF=          1.000000    Z1=       120.000000        CICER=          0.035100
   PHI=          0.950000    Z2=        60.000000        CIEXP=          1.000000
     R=          0.066667    Z3=       360.000000        BYEAR=              1979
    DF=          1.000000    Z4=       240.000000   Z5=          0.0          Z6=         1.000000

     CALCULATED VALUES         SET          SUM TO  1.2.1.1                         $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                                  1.170

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                0.035

  #RM =T / M                                                                     1.000

  E   =1.0 + LOG(PHI) / LOG(2.0)                                                 0.926

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                     3.184


  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                0.024

  CIPS=CTB*Z4/Z2                                                                     0.098

      CRCI  =CTB  X R                                                                0.002
             PRE-IOC  CRCI =CRCI X Z6                                                0.002
             POST-IOC CRCI =CRCI X (1.0-Z6)                                          0.0

      CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                   0.042

  COMMENTS
      1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     1.000000   0.030000   0.036000
      SERVICE DUTY CYCLE AT 2.5 YEARS ITH 15 YEAR LIFE SPAN.  120 FOR RC1.
      Z4=120 FOR SCB AND 120 FOR ROTATION
```

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE    1.2.1.1.9  CABLE/CATENARY DISPENSER MACHINES

                 INPUT PARAMETERS                                    INPUT COEFFICIENTS

     T=         1.000000    TF=        1.000000          CDCER=          2.573999
     M=         1.000000   O&M=        0.073710          CDEXP=          1.000000
    CF=         1.000000    Z1=       84.000000          CICER=          0.351000
   PHI=         0.980000    Z2=       60.000000          CIEXP=          1.000000
     R=         0.0         Z3=       84.000000          BYEAR=              1979
    DF=         1.000000    Z4=       84.000000    Z5=         0.0          Z6=          1.000000

 CALCULATED VALUES          SET          SUM TO  1.2.1.1                          $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                    2.574

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                  0.351

#RM =T / M                                                                        1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                    0.971

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                      26.660


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))            ) / Z3                0.317

CIPS=CTB*Z4/Z2                                                                       0.444

   CRCI  =CTB  X R                                                                   0.0
         PRE-IOC  CRCI =CRCI X Z6                                                    0.0
         POST-IOC CRCI =CRCI X (1.0-Z6)                                              0.0

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                      0.074

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      2.200000    0.300000    0.063000
   SERVICE/DUTY CYCLE 2.5 YEARS.  30 YEAR LIFE SPAN WITH MAINTENANCE
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.1.1.10 ANTENNA PANEL INS. EQPT.

```
        INPUT PARAMETERS                                    INPUT COEFFICIENTS

  T=      1.000000   TF=     1.000000       CDCER=    702.000000
  M=      1.000000   U&M=    1.170000       CDEXP=      1.000000
 CF=      1.000000   Z1=     1.000000       CICER=    234.000015
PHI=      0.980000   Z2=    60.000000       CIEXP=      1.000000
  R=      0.0        Z3=     1.000000       BYEAR=          1979
 DF=      0.133333   Z4=     1.000000   Z5=       0.0        Z6=       1.000000

 CALCULATED VALUES      SET       SUM TO  1.2.1.1                   $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                     93.600

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                  234.000

#RM =T / M                                                          1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                      0.971

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                       234.318

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))       ) / Z3     234.318

CIPS=CTB*Z4/Z2                                                         3.905

   CRCI  =CTB  X R                                                     0.0
          PRE-IOC  CRCI =CRCI X Z6                                     0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                               0.0

   CU&M  =U&M OR CTB*Z5/Z2/ENYR                                        1.170

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE   600.000000  200.000000   1.000000
   SERVICE/DUTY CYCLE AT 70 DAYS PER SATELLITE.  LIFE OF 30 YEARS
   WITH MAINTENANCE
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.1.1.11 GANTRY/CRANES

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	1.000000	TF=	1.000000			CDCER=	19.889999		
M=	1.000000	O&M=	0.280800			CDEXP=	1.000000		
CF=	1.000000	Z1=	12.000000			CICER=	9.360001		
PHI=	0.950000	Z2=	60.000000			CIEXP=	1.000000		
R=	0.0	Z3=	12.000000			BYEAR=	1979		
DF=	0.800000	Z4=	12.000000	Z5=	0.0			Z6=	1.000000

CALCULATED VALUES SET SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	15.912
CLRM=CICER X (M)XX(CIEXP) X CF X TF	9.360
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	99.490
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	8.291
CIPS=CTB*Z4/Z2	1.658
CRCI =CTB X R	0.0
PRE-IOC CRCI =CRCI X Z6	0.0
POST-IOC CRCI =CRCI X (1.0-Z6)	0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR	0.261

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 17.000000 8.000000 0.240000
SERVICE/DUTY CYCLE OF 4 YEARS OVER OPTION. LIFE SPAN OF 30 YEARS WITH
MAINTENANCE

RUCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.1.1.12 CARGO STORAGE DEPOTS

```
                   INPUT PARAMETERS                                          INPUT COEFFICIENTS

   T=          1.000000     TF=        1.000000         CDCER=          17.549988
   M=          1.000000     U&M=       0.023400         CDEXP=           1.000000
  CF=          1.000000     Z1=        4.000000         CICER=           2.340000
 PHI=          0.950000     Z2=       60.000000         CIEXP=           1.000000
   R=          0.0          Z3=        4.000000         BYEAR=               1979
  DF=          0.250000     Z4=        4.000000   Z5=            0.0          Z6=          1.000000

  CALCULATED VALUES         SET          SUM TO  1.2.1.1                              $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                        4.387

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                      2.340

#RM =T / M                                                                           1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                       0.926

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                           8.844


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                      2.211

CIPS=CTB*Z4/Z2                                                                           0.147

    CRCI  =CTB  X R                                                                      0.0
          PRE-IOC  CRCI =CRCI X Z6                                                       0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                                 0.0

    CO&M  =U&M OR CTB*Z5/Z2/ENYR                                                         0.023

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE    15.000000    2.000000    0.020000
    STRUCTURE,ENCLOSURES, ELEVATORS, CONVEYORS, SPECIAL HANDLING EQUIPMENT
    30 YEARLIFE WITH MAINTENANCE.
```

```
                ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE   1.2.1.1.13 FAB FIXTURE

                       INPUT PARAMETERS                              INPUT COEFFICIENTS

     T=     1648900.00        TF=          1.000000        CDCER=          0.026910
     M=        5000.00000     O&M=         0.241251        CDEXP=          0.800000
    CF=           1.000000    Z1=          1.000000        CICER=          0.000058
   PHI=           1.000000    Z2=         60.000000        CIEXP=          1.000000
     R=           0.0         Z3=          1.000000        BYEAR=              1979
    DF=           1.000000    Z4=          1.000000   Z5=          0.0        Z6=          1.000000

     CALCULATED VALUES        KG        SUM TO  1.2.1.1                       $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                            2533.200

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                             0.293

 #RM =T / M                                                                329.780

 E   =1.0 + LOG(PHI) / LOG(2.0)                                              1.000

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                 96.461


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3         96.461

 CIPS=CTB*Z4/Z2                                                                  1.608

     CRCI  =CTB  X R                                                             0.0
           PRE-IOC  CRCI =CRCI X Z6                                              0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                        0.0

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                0.241

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.023000    0.000050    0.206197
     30 YEAR LIFE WITH MAINTENANCE
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.1.1.14 AIRLOCK DOCKING MODULE (ADM)

```
                    INPUT PARAMETERS                                     INPUT COEFFICIENTS

   T=     2500.00000     TF=      1.000000           CDCER=        0.0
   M=     2500.00000    O&M=      0.0                CDEXP=        0.0
  CF=        1.000000    Z1=     17.000000           CICER=        0.007062
 PHI=        0.980000    Z2=     60.000000           CIEXP=        1.000000
   R=        0.009444    Z3=     34.000000           BYEAR=            1979
  DF=        1.000000    Z4=     17.000000    Z5=          0.0        Z6=          1.000000

   CALCULATED VALUES          KG          SUM TO  1.2.1.1                  $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                            0.0

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                         17.655

 #RM =T / M                                                                 1.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                             0.971

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                             283.493


 CTR =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3          16.370

 CIPS=CTB*Z4/Z2                                                               4.638

     CRCI  =CTB  X R                                                          0.155
         PRE-IOC  CRCI =CRCI X Z6                                             0.155
         POST-IOC CRCI =CRCI X (1.0-Z6)                                       0.0

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                             0.0

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0        0.006036    0.0
     SEE 1.2.1.2.1 FOR DDT&E.  15 YEAR LIFE.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.1.1.15 BASE MGMT. MODULE (BMM)

```
                 INPUT PARAMETERS                                INPUT COEFFICIENTS

    T=      27000.0000     TF=       1.000000           CDCER=         0.0
    M=      27000.0000    O&M=       0.0                CDEXP=         0.0
   CF=          1.000000   Z1=       4.000000           CICER=         0.013450
  PHI=          0.980000   Z2=      60.000000           CIEXP=         1.000000
    R=          0.002220   Z3=       8.000000           BYEAR=            1979
   DF=          1.000000   Z4=       4.000000    Z5=        0.0           Z6=          1.000000

    CALCULATED VALUES          KG        SUM TO  1.2.1.1                 $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                          0.0

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                      363.159

 #RM =T / M                                                              1.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                          0.971

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                          1420.228


 CTB =((CLRM/E)X((#RM X     Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3      349.551

 CIPS=CTB*Z4/Z2                                                            23.303

     CRCI  =CTB  X R                                                        0.776
         PRE-IOC  CRCI =CRCI X Z6                                           0.776
         POST-IOC CRCI =CRCI X (1.0-Z6)                                     0.0

     CU&M  =O&M OR CTB*Z5/Z2/ENYR                                           0.0

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0        0.011496    0.0
     SEE 1.2.2.1.1 FOR DDT&E.  15 YEARLIFE.
```

```
                ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.2.1.1.16 POWER MODULE (PM)

                    INPUT PARAMETERS                                  INPUT COEFFICIENTS

     T=          250.000000     TF=          1.000000       CDCER=          0.0
     M=          250.000000    O&M=          0.0            CDEXP=          0.0
    CF=            1.000000     Z1=          4.000000       CICER=          1.287000
   PHI=            0.980000     Z2=         60.000000       CIEXP=          1.000000
     R=            0.002220     Z3=          8.000000       BYEAR=             1979
    DF=            1.000000     Z4=          4.000000    Z5=          0.0       Z6=          1.000000

     CALCULATED VALUES            KW         SUM TO  1.2.1.1                     $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 0.0

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                             321.750

 #RM =T / M                                                                     1.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                                 0.971

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                 1258.288


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3            309.693

 CIPS=CTB*Z4/Z2                                                                  20.646

     CRC1  =CTB  X R                                                              0.688
           PRE-IOC  CRC1 =CRC1 X Z6                                               0.688
           POST-IOC CRC1 =CRC1 X (1.0-Z6)                                         0.0

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                 0.0

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0        1.100000    0.0
     SEE 1.2.2.1.2 FOR DDT&E.  15 YEAR LIFE
```

```
                 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE   1.2.1.1.17 PRESSURIZED STORAGE MODULE (PSM)

                  INPUT PARAMETERS                                    INPUT COEFFICIENTS

     T=      15000.0000      TF=         1.000000          CDCER=         0.061909
     M=      15000.0000     U&M=         0.0               CDEXP=         1.000000
    CF=         1.000000     Z1=         4.000000          CICER=         0.016069
   PHI=         0.980000     Z2=        60.000000          CIEXP=         1.000000
     R=         0.002220     Z3=         8.000000          BYEAR=            1979
    DF=         1.000000     Z4=         4.000000    Z5=          0.0         Z6=          1.000000

     CALCULATED VALUES           KG          SUM TO  1.2.1.1                     $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                             928.641

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                           241.032

  #RM =T / M                                                                   1.000

  E    =1.0 + LOG(PHI) / LOG(2.0)                                              0.971

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                942.619


  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3            232.000

  CIPS=CTB*Z4/Z2                                                                 15.467

     CRCI   =CTB   X R                                                            0.515
              PRE-IOC   CRCI =CRCI X Z6                                           0.515
              POST-IOC CRCI =CRCI X (1.0-Z6)                                      0.0

     CU&M   =U&M OR CTP*Z5/Z2/ENYR                                                0.0

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE     0.052914    0.013734    0.0
     15 YEAR LIFE
```

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
   TABLE    1.2.1.2.1  AIRLOCK DOCKING MODULE-ADM

                     INPUT PARAMETERS                                      INPUT COEFFICIENTS

       T=         2500.00000      TF=          1.000000          CDCER=          0.014579
       M=         2500.00000     O&M=          0.0               CDEXP=          1.000000
      CF=            1.000000     Z1=          5.000000          CICER=          0.007062
     PHI=            0.980000     Z2=         60.000000          CIEXP=          1.000000
       R=            0.002770     Z3=         10.000000          BYEAR=              1979
      DF=            1.000000     Z4=          5.000000     Z5=          0.0          Z6=         1.000000

    CALCULATED VALUES            KG           SUM TO  1.2.1.2                     $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 36.448

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               17.655

 #RM =T / M                                                                      1.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                                  0.971

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                    85.893


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               16.902

 CIPS=CTB*Z4/Z2                                                                     1.408

    CRCI  =CTB  X R                                                                 0.047
           PRE-IOC  CRCI =CRCI X Z6                                                 0.047
           POST-IOC CRCI =CRCI X (1.0-Z6)                                           0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                    0.0

 COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.012461    0.006036    0.0
    15 YEAR LIFE
```

```
              ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
  TABLE   1.2.1.2.2  CREW HABITABILITY MODULE-CHM

              INPUT PARAMETERS                                    INPUT COEFFICIENTS

    T=      27000.0000      TF=        1.000000           CDCER=         0.0
    M=      27000.0000     U&M=        0.0                CDEXP=         0.0
   CF=         1.000000     Z1=       17.000000           CICER=         0.004411
  PHI=         0.980000     Z2=       60.000000           CIEXP=         1.000000
    R=         0.009444     Z3=       34.000000           BYEAR=            1979
   DF=         1.000000     Z4=       17.000000   Z5=           0.0         Z6=          1.000000

  CALCULATED VALUES         KG          SUM TO  1.2.1.2                    $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                           0.0

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                       119.094

 #RM =T / M                                                                1.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                            0.971

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                           1912.313

 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3       110.427

 CIPS=CTB*Z4/Z2                                                             31.288

    CRCI  =CTB  X R                                                          1.043
          PRE-IOC  CRCI =CRCI X Z6                                           1.043
          POST-IOC CRCI =CRCI X (1.0-Z6)                                     0.0

    CO&M  =U&M OR CTB*Z5/Z2/ENYR                                             0.0

 COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE     0.0        0.003770     0.0
    SEE 1.2.2.2.1 FOR DDT&E.  15 YEAR LIFE
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.1.2.3 CONSUMABLES LOGISTICS MODULE-CLM

```
              INPUT PARAMETERS                                      INPUT COEFFICIENTS

   T=     5000.00000     TF=        1.000000        CDCER=          0.0
   M=     5000.00000     O&M=       0.0             CDEXP=          0.0
  CF=        1.000000    Z1=        9.000000        CICER=          0.016380
 PHI=        0.980000    Z2=       60.000000        CIEXP=          1.000000
   R=        0.005000    Z3=       18.000000        BYEAR=             1979
  DF=        1.000000    Z4=        9.000000   Z5=           0.0       Z6=          1.000000

   CALCULATED VALUES           KG          SUM TO  1.2.1.2                    $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                               0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                             81.900

#RM =T / M                                                                     1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                 0.971

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                 707.469

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3              77.242

CIPS=CTB*Z4/Z2                                                                  11.586

    CRCI  =CTB  X R                                                             0.386
          PRE-IOC  CRCI =CRCI X Z6                                              0.386
          POST-IOC CRCI =CRCI X (1.0-Z6)                                        0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0       0.014000    0.0
    SEE 1.2.2.2.2 FOR DDT&E.  15 YEAR LIFE.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.1.2.4 SHIELDING

```
                INPUT PARAMETERS                                               INPUT COEFFICIENTS

   T=     11000.0000      TF=       1.000000          CDCER=          0.182520
   M=     11000.0000     U&M=       0.0               CDEXP=          1.000000
  CF=       1.000000      Z1=       8.000000          CICER=          0.118170
 PHI=       0.990000      Z2=      60.000000          CIEXP=          0.355000
   R=       0.004440      Z3=      16.000000          BYEAR=              1979
  DF=       0.200000      Z4=       8.000000    Z5=              0.0       Z6=          1.000000

 CALCULATED VALUES         KG          SUM TO  1.2.1.2                              $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                   401.544

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                   3.215

#RM =T / M                                                                          1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                      0.971

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                       24.757

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                   3.042

CIPS=CTB*Z4/Z2                                                                        0.406

   CRCI  =CTB  X R                                                                    0.014
         PRE-IOC  CRCI =CRCI X Z6                                                     0.014
         POST-IOC CRCI =CRCI X (1.0-Z6)                                               0.0

   CU&M  =U&M OR CTB*Z5/Z2/ENYR                                                       0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE      0.156000      0.101000      0.0
   15 YEAR LIFE
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.1.2.5 CREW SUPPORT MODULE-CSM

```
            INPUT PARAMETERS                                              INPUT COEFFICIENTS

   T=      15000.0000     TF=       1.000000              CDCER=         0.014545
   M=      15000.0000     O&M=      0.0                   CDEXP=         1.000000
  CF=          1.000000   Z1=       3.000000              CICER=         0.006784
 PHI=          0.980000   Z2=      60.000000              CIEXP=         1.000000
   R=          0.001666   Z3=       6.000000              BYEAR=             1979
  DF=          1.000000   Z4=       3.000000    Z5=           0.0           Z6=            1.000000

  CALCULATED VALUES       KG          SUM TO  1.2.1.2                          $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                               218.182

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                             101.755

#RM =T / M                                                                    1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                0.971

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                  300.206


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3              98.603

CIPS=CTB*Z4/Z2                                                                    4.930

    CRCI  =CTB  X R                                                               0.164
          PRE-IOC  CRCI =CRCI X Z6                                                0.164
          POST-IOC CRCI =CRCI X (1.0-Z6)                                          0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                  0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.012432    0.005798    0.0
    15 YEAR LIFE
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.1.3.1 OPERATIONS, CONSTRUCTION CREW

```
                  INPUT PARAMETERS                                  INPUT COEFFICIENTS

    T=        1268.00000      TF=          1.000000          CDCER=          0.0
    M=           1.000000    U&M=          0.0               CDEXP=          0.0
   CF=           1.000000     Z1=          1.000000          CICER=          0.073008
  PHI=           1.000000     Z2=         60.000000          CIEXP=          1.000000
    R=           0.0          Z3=         31.000000          BYEAR=             1979
   DF=           1.000000     Z4=         30.000000     Z5=          0.0         Z6=          1.000000

    CALCULATED VALUES         MEN          SUM TO  1.2.1.3                        $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                  0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                0.073

#RM =T / M                                                                     1268.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                    1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                    92.574


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))           ) / Z3              92.574

CIPS=CTB*Z4/Z2                                                                    46.287

   CRCI  =CTB  X R                                                                 0.0
         PRE-IOC  CRCI =CRCI X Z6                                                  0.0
         POST-IOC CRCI =CRCI X (1.0-Z6)                                            0.0

   CO&M  =U&M OR CTM*Z5/Z2/ENYR                                                    0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE     0.0        0.062400    0.0
   TFU REQUIRES ONE YEAR TO BUILD.  60 SATELLITE OPTION BUILT AT RATE OF 2
   PER YEAR.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.1.3.2 ORBITAL OPERATIONS,CONST. PROV.

```
                     INPUT PARAMETERS                                  INPUT COEFFICIENTS

     T=     1643328.00        TF=         1.000000           CDCER=          0.0
     M=          3.600000     O&M=        0.0                CDEXP=          0.0
    CF=          1.000000     Z1=         1.000000           CICER=          0.000026
   PHI=          1.000000     Z2=        60.000000           CIEXP=          1.000000
     R=          0.0          Z3=        31.000000           BYEAR=              1979
    DF=          1.000000     Z4=        30.000000    Z5=           0.0          Z6=            1.000000

     CALCULATED VALUES           KG          SUM TO  1.2.1.3                        $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                                      0.0

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                    0.000

  #RM =T / M                                                                     456479.937

  E    =1.0 + LOG(PHI) / LOG(2.0)                                                    1.000

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                        42.299


  CIB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))           ) / Z3                  42.299

  CIPS=CTB*Z4/Z2                                                                        21.150

     CRCI  =CTB  X R                                                                     0.0
           PRE-IOC  CRCI =CRCI X Z6                                                      0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                                0.0

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                        0.0

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0         0.000022     0.0
     1643328 KG OF PROVISIONS ANNUALLY FOR TOTAL OF A 1268 PERSON CREW.
     $26 KG AT 3.6 KG/PERSON/DAY
```

1.2.2 LOGISTICS SUPPORT FACILITIES—LEO

This element includes hardware, software and operations required in LEO to support construction and operations/maintenance of the satellite system. Included are crew life support facilities, cargo and propellant depots, and vehicle servicing facilities necessary for the transfer of cargo and personnel destined for a construction mobile maintenance base activity in GEO.

LEO support operations require a permanent crew of 30. These personnel provide supervision over the transfer of payloads between the HLLV and OTV's. They also perform scheduled maintenance required by the electric propulsion OTV such as the changeout of ion thruster screens. Included are work and crew support facilities (Table 1.2-4) plus required operational support.

Table 1.2-4. LEO Base Modules

SYSTEM DESCRIPTION	WORK SUPPORT FACILITIES	CREW SUPPORT FACILITIES
CREW HABITABILITY MODULE (CHM)		1
CONSUMABLES LOGISTICS MODULE (CLM)		1
BASE MANAGEMENT MODULE (BMM)	1	
CREW SUPPORT MODULE/EVA (CSM/EVA)		1
POWER MODULE (PM)	1	
AIRLOCK DOCKING MODULE (ADM)	1	

1.2.2.1 WORK SUPPORT FACILITIES

This element includes facilities and equipment required to provide logistics support in LEO. Included are HLLV and OTV docking stations, payload handling equipment, and cargo and propellant storage depots. Excluded are facilities related to crew support. A 100 kW solar array power module, the airlock docking module, and a base management module are work support facilities. Cost estimates were based on Rockwell Space Station studies.

1.2.2.2 CREW SUPPORT FACILITIES

This element includes facilities and equipment required for the life support and well-being of the crew members. Included are living quarters, recreation facilities, and health facilities at LEO.

The crew habitability module and crew support module/EVA are the same basic configuration as for those on the SCB. However, the crew support module has an airlock and EVA preparation area. A consumables logistics module is the third element of crew support facilities. CERs used for crew support facilities were based upon Rockwell Space Station studies.

1.2.2.3 OPERATIONS

This element includes planning, development, and conduct of operations at the logistics support facility. It includes both direct and support personnel and the expendable maintenance supplies required for logistics support.

An average of 30 crew members are required at the LEO Base to support orbital operations. Engineering estimates were made of the operations and consumable requirements at LEO.

1.2.2.4 COST ESTIMATES

LEO base cost estimates covering work, crew, and operational elements are included in Table 1.2-5.

Table 1.2-5. LEO Base Cost Estimates

WBS TABLE NO's	DESCRIPTION
1.2.2.1.1, 1.2.2.1.2, and 1.2.2.1.3	Work Support Facilities
1.2.2.2.1, 1.2.2.2.2, and 1.2.2.2.3	Crew Support Facilities
1.2.2.3.1, 1.2.2.3.2	Operations

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION, 1980

TABLE 1.2.2.1.1 BASE MGMT. MODULE-8MM

```
                    INPUT PARAMETERS                                           INPUT COEFFICIENTS

     T=       27000.0000       IF=         1.000000          CDCER=          0.106816
     M=       27000.0000      O&M=         0.0               CDEXP=          1.000000
    CF=           1.000000     Z1=         1.000000          CICER=          0.013450
   PHI=           0.980000     Z2=        60.000000          CIEXP=          1.000000
     R=           0.000555     Z3=         2.000000          BYEAR=              1979
    DF=           1.000000     Z4=         0.800000   Z5=         0.200000    Z6=         0.800000

    CALCULATED VALUES          KG          SUM TO  1.2.2.1                           $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                                    2884.040

 CLRM=CICER X (M)XX(CIEXP) X CF X IF                                                   363.159

 *RM =T / M                                                                          1.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                                      0.971

 CTFU=(CLRM / E)X((*RM X Z1+.5)XX(E) -0.5XX(E))                                        363.652


 CTB =((CLRM/E)X((*RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                   359.830

 CIPS=CTB*Z4/Z2                                                                          4.798

     CRCI  =CTB  X R                                                                     0.200
           PRE-IOC  CRCI =CRCI X Z6                                                      0.160
           POST-IOC CRCI =CRCI X (1.0-Z6)                                                0.040

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                        0.040

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.091296    0.011496    0.0
     15 YEAR LIFE.  80 PERCENT OF 8MM ASSOCIATED WITH CONSTRUCTION ACTIVITIES
```

```
            ROCKWELL SFS CR-2 REFERENCE CONFIGURATION,1980
TABLE   1.2.2.1.2   POWER MODULE-PM

              INPUT PARAMETERS                                      INPUT COEFFICIENTS

  T=      250.000000    TF=        1.000000          CDCER=         1.638000
  M=      250.000000    O&M=       0.0               CDEXP=         1.000000
 CF=        1.000000    Z1=        1.000000          CICER=         1.287000
PHI=        0.980000    Z2=       60.000000          CIEXP=         1.000000
  R=        0.000555    Z3=        2.000000          BYEAR=             1979
 DF=        1.000000    Z4=        0.800000    Z5=         0.200000    Z6=            0.800000

  CALCULATED VALUES          KW       SUM TO  1.2.2.1                          $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                               409.500

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                             321.750

#RM =T / M                                                                    1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                0.971

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                  322.187


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3              318.801

CIPS=CTB*Z4/Z2                                                                    4.251

    CRCI  =CTB   X R                                                              0.177
          PRE-IOC  CRCI =CRCI X Z6                                                0.142
          POST-IOC CRCI =CRCI X (1.0-Z6)                                          0.035

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                  0.035

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     1.400000    1.100000    0.0
    15 YEAR LIFE.  80 PERCENT OF PM ASSOCIATED WITH CONSTRUCTION ACTIVITIES.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.2.1.3 AIRLOCK DOCKING MODULE - ADM

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	2500.00000	IF=	1.000000			CDCER=	0.0
M=	2500.00000	O&M=	0.0			CDEXP=	0.0
CF=	1.00000C	Z1=	1.000000			CICER=	0.007062
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.000555	Z3=	2.000000			BYEAR=	1979
DF=	1.00000C	Z4=	0.800000	Z5=	0.200000	Z6=	0.800000

CALCULATED VALUES KG SUM TO 1.2.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X IF	17.655
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	17.679
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	17.493
CIPS=CTB*Z4/Z2	0.233
CRC1 =CTB X R	0.010
PRE-IOC CRCI =CRC1 X Z6	0.008
POST-IOC CRCI =CRC1 X (1.0-Z6)	0.002
CO&M =O&M OR CTB*Z5/Z2/ENYR	0.002

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.0 0.006036 0.0
SEE 1..2.1.2.1 FOR DDT&E. 15 YEAR LIFE. 80 PERCENT OF ADM ASSOCIATED
WITH CONSTRUCTION ACTIVITIES

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.2.2.2.1  CREW HABITABILITY MODULE-CHM

                   INPUT PARAMETERS                                 INPUT COEFFICIENTS

      T=       27000.0000       TF=          1.000000          CDCER=          0.011365
      M=       27000.0000      O&M=          0.0               CDEXP=          1.000000
     CF=          1.000000      Z1=          1.000000          CICER=          0.004411
    PHI=          0.980000      Z2=         60.000000          CIEXP=          1.000000
      R=          0.000550      Z3=          2.000000          BYEAR=              1979
     DF=          1.000000      Z4=          0.800000    Z5=           0.200000    Z6=          0.800000

     CALCULATED VALUES           KG           SUM TO  1.2.2.2                           $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                                       306.865

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                     119.094

  #RM =T / M                                                                            1.000

  E    =1.0 + LOG(PHI) / LOG(2.0)                                                       0.971

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                          119.256


  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                  118.003

  CIPS=CTB*Z4/Z2                                                                            1.573

      CRCI  =CTB  X R                                                                       0.065
            PRE-IOC  CRCI =CRCI X Z6                                                        0.052
            POST-IOC CRCI =CRCI X (1.0-Z6)                                                  0.013

      CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                          0.013

  COMMENTS
      1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.009714     0.003770    0.0
      15 YEAR LIFE.  80 PERCENT OF CHM ASSOCIATED WITH CONSTRUCTION
      ACTIVITIES.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.2.2.2 CONSUMABLES LOGISTICS MODULE CLM

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	5000.00000	TF=	1.000000			CDCER=	0.062010		
M=	5000.00000	O&M=	0.0			CDEXP=	1.000000		
CF=	1.000000	Z1=	1.000000			CICER=	0.016380		
PHI=	0.960000	Z2=	60.000000			CIEXP=	1.000000		
R=	0.000555	Z3=	2.000000			BYEAR=	1979		
DF=	1.000000	Z4=	0.800000	Z5=	0.200000			Z6=	0.800000

CALCULATED VALUES	KG	SUM TO 1.2.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			310.050
CLRM=CICER X (M)XX(CIEXP) X CF X TF			81.900
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			82.011
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			81.149
CIPS=CTB*Z4/Z2			1.082
CRCI =CTB X R			0.045
PRE-IOC CRCI =CRCI X Z6			0.036
POST-IOC CRCI =CRCI X (1.0-Z6)			0.009
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.009

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.053000 0.014000 0.0
15 YEAR LIFE. 80 PERCENT OF CLM ASSOCIATED WITH CONSTRUCTION
ACTIVITIES.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.2.2.3 CREW SUPPORT MODULE/EVA

```
                 INPUT PARAMETERS                                          INPUT COEFFICIENTS

     T=       27000.0000      TF=        1.000000              CDCER=          0.014545
     M=       27000.0000      O&M=       0.0                   CDEXP=          1.000000
    CF=           1.000000    Z1=        1.000000              CICER=          0.006784
   PHI=           0.980000    Z2=       60.000000              CIEXP=          1.000000
     R=           0.000555    Z3=        2.000000              BYEAR=              1979
    DF=           1.000000    Z4=        0.800000     Z5=            0.200000  Z6=          0.800000

   CALCULATED VALUES           KG          SUM TO  1.2.2.2                             $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                                       392.727

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                     183.159

 #RM =T / M                                                                            1.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                                        0.971

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                          183.408

 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))            ) / Z3                   181.480

 CIPS=CTB*Z4/Z2                                                                            2.420

     CRCI  =CTB  X R                                                                       0.101
           PRE-IOC  CRCI =CRCI X Z6                                                        0.081
           POST-IOC CRCI =CRCI X (1.0-Z6)                                                  0.020

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                          0.020

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.012432    0.005798    0.0
     15 YEAR LIFE.  80 PERCENT OF CSM/EVA ASSOCIATED WITH CONSTRUCTION
     ACTIVITIES.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.2.3.1 LEO OPERATIONS CREW

```
           INPUT PARAMETERS                                  INPUT COEFFICIENTS

   T=      30.000000     TF=      1.000000         CDCER=        0.0
   M=       1.000000    O&M=      0.0              CDEXP=        0.0
  CF=       1.000000     Z1=      1.000000         CICER=        0.073008
 PHI=       1.000000     Z2=     60.000000         CIEXP=        1.000000
   R=       0.0          Z3=     30.500000         BYEAR=           1979
  DF=       1.000000     Z4=     24.000000   Z5=         6.000000    Z6=        0.800000

  CALCULATED VALUES    PERSONS         SUM TO  1.2.2.3                    $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                            0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                          0.073

#RM =T / M                                                           30.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                        1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                               2.190


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3          2.190

CIPS=CTB*Z4/Z2                                                               0.876

    CRCI  =CTB  X R                                                          0.0
        PRE-IOC  CRCI =CRCI X Z6                                             0.0
        POST-IOC CRCI =CRCI X (1.0-Z6)                                       0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                             0.007

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0       0.062400    0.0
    30 PERSON CREW AT LEO.  80 PERCENT OF CREW ASSOCIATED WITH CONSTRUCTION
    ACTIVITIES
```

```
                 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE    1.2.2.3.2  LEO CREW PROVISIONS

              INPUT PARAMETERS                                    INPUT COEFFICIENTS

  T=      38880.0000    TF=       1.000000        CDCER=        0.0
  M=         3.600000   U&M=      0.0             CDEXP=        0.0
  CF=        1.000000   Z1=       1.000000        CICER=        0.000026
  PHI=       1.000000   Z2=      60.000000        CIEXP=        1.000000
  R=         0.0        Z3=      30.500000        BYEAR=        1979
  DF=        1.000000   Z4=      24.000000    Z5=       6.000000    Z6=      0.800000

  CALCULATED VALUES          KG          SUM TO  1.2.2.3                 $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF
                                                                          0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF
                                                                          0.000
#RM =T / M
                                                                   10799.996
E   =1.0 + LOG(PHI) / LOG(2.0)
                                                                      1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))
                                                                          1.001

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3        1.001

CIPS=CTB*Z4/Z2
                                                                          0.400
    CRCI  =CTB  X R
          PRE-IUC  CRCI =CRCI X Z6                                        0.0
          POST-IUC CRCI =CRCI X (1.0-Z6)                                  0.0
                                                                          0.0
    CO&M  =U&M OR CTB*Z5/Z2/ENYR
                                                                          0.003
COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE       0.0        0.000022    0.0
   $26/KG AT 3.6 KG/PERSON/DAY.  30 PERSON CREW.  80 PERCENT OF CREW
   PROVISIONS ASSOCIATED WITH CONSTRUCTION ACTIVITIES.
```

1.2.3 SATELLITE O&M SUPPORT FACILITIES

This element includes the facilities, equipment, and operations required in GEO to support operations and maintenance of satellite systems after IOC. Included are on-orbit monitor and control facilities, life support facilities, and equipment required to provide confortable safe living quarters for resident crew members during O&M activities, plus storage module facilities.

Post IOC-O&M activity and the replacement of capital investment systems is carried out under the concept of mobile maintenance facilities traveling from satellite to satellite by using the SCB as a home base. Table 1.2-6 identifies work and crew support facilities associated with SCB and MMB missions.

Table 1.2-6. Satellite O&M Facilities

SYSTEM DESCRIPTION	ABBREVIATION	WORK SUPPORT FACILITIES	CREW SUPPORT FACILITIES
AIRLOCK DOCKING MODULE	ADM	12	
CREW HABITABILITY MODULE	CHM		8
CONSUMABLES LOGISTICS MODULE	CLM		8
BASE MANAGEMENT MODULE	BMM	64	
POWER MODULE	PM	12	
PRESSURIZED STORAGE MODULE	PSM	12	

A mobile maintenance base is scheduled to provide an average of 45 days of service to individual satellites on an annual rotation basis. Table 1.2-7 identifies MMB rotations against a satellite option and summarizes crew requirements for SCB and MMB categories.

1.2.3.1 WORK SUPPORT FACILITIES

This element includes work oriented facilities and equipment required at the SCB and on the MMB, along with those needed at the satellite to satisfy operational and maintenance needs of the satellite system during its operation.

Of the 12 ADM's (reference Table 1.2-7) - 4 are located on the SCB and 8 are located on the contingent of MMB's (mobile maintenance bases). Sixty MMB's are assigned as one per satellite with 4 more located in the SCB. Four PM's, and PSM's are located on the SCB to support satellite O&M activity for the option. One set each of the other 8 PM's and PSM's is located on the individual MMB's. One CHM and CLM is also located on each of the MMB's.

Table 1.2-7. MMB Requirements

CONSTRUCTION PERIOD (YEARS)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
SATELLITE IOC's	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61
MMB 1																															
MMB 2																															
MMB 3																															
MMB 4																															
MMB 5																															
MMB 6																															
MMB 7																															
MMB 8																															
CREW																															
SCB	8	8	8	8	8	8	8	8	8/16	16	16	16	16	16	16	16	16/24	24	24	24	24	24	24	24	24/32	32	32	32	32	32	32
MMB	30	30	30	30	30/60	60	60	60	60/90	90	90	90	90/120	120	120	120	120/150	150	150	150	150/180	180	180	180	180/210	210	210	210	210/240	240	240

The MMB located on each satellite incorporates a monitoring and fault isolation capability for SPS satellite subsystems as well as the controls required for alternate operational modes and functional isolation of selected subsystems for maintenance. CER's are based on Rockwell Space Station study data.

1.2.3.2 CREW SUPPORT FACILITIES

This element includes facilities and equipment required for life support and well-being of the crew members. Included are living quarters, recreation facilities, and health facilities located on the MMB. Costs of CHM and CLM modules are based on Rockwell's Space Station studies.

1.2.3.3 OPERATIONS

This element includes the planning, development, and conduct of operations at the O&M support facility. It encompasses both direct and indirect personnel plus expendable maintenance supplies required in GEO for satellite oeprations and maintenance.

O&M crew are located on the SCB and MMB. Each satellite is serviced for an average period of 45 days per year.

1.2.3.4 COST ESTIMATES

Operational support costs are identified in Table 1.2-8.

Table 1.2-8. Operational Cost Tables

WBS TABLE NO's	DESCRIPTION
1.2.3.1.1 thru 1.2.3.1.4	Work Support Facilities
1.2.3.2.1, 1.2.3.2.2	Crew Support Facilities
1.2.3.3.1 (SCB Crew), 1.2.3.3.2 (MMB Crew), 1.2.3.3.3 (SCB Provisions) 1.2.3.3.4 (MMB Provisions)	Operations

```
                    ROCKWELL SPS CP-2 REFERENCE CONFIGURATION,1980
      TABLE    1.2.3.1.1   AIRLOCK DOCKING MODULE-ADM

                    INPUT PARAMETERS                                         INPUT COEFFICIENTS

      T=        2500.00000    TF=        1.000000          CDCER=          0.0
      M=        2500.00000   O&M=        0.0               CDEXP=          0.0
     CF=           1.000000   Z1=        2.000000          CICER=          0.007062
    PHI=           0.980000   Z2=       60.000000          CIEXP=          1.000000
      R=           0.006666   Z3=       24.000000          BYEAR=             1979
     DF=           1.000000   Z4=        0.0        Z5=       12.000000    Z6=            0.0

      CALCULATED VALUES          KG         SUM TO  1.2.3.1                        $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 0.0

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                              17.655

  #RM =T / M                                                                     1.000

  E   =1.0 + LOG(PHI) / LOG(2.0)                                                 0.971

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                   34.987


  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3              16.525

  CIPS=CTB*Z4/Z2                                                                    0.0

      CRCI  =CTB  X R                                                               0.110
             PRE-IOC  CRCI =CRCI X Z6                                               0.0
             POST-IOC CRCI =CRCI X (1.0-Z6)                                         0.110

      CO&M  =O&M OR CTR*Z5/Z2/ENYR                                                  0.110

  COMMENTS
      1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0         0.006036    0.0
      SEE 1.2.1.2.1 FOR ODT&E.  15 YEAR LIFE.  4 ADM'S LOCATED ON SCB.
      8 ADM'S FOR MMB'S.  ONE ADM ON SCB AND ONE ADM ON MMB FOR TFU
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.3.1.2 BASE MGMT MODULE-BMM

```
                 INPUT PARAMETERS                                      INPUT COEFFICIENTS

   T=     27000.0000     TF=        1.000000              CDCER=         0.0
   M=     27000.0000     O&M=       0.0                   CDEXP=         0.0
  CF=         1.000000   Z1=        2.000000              CICER=         0.013450
 PHI=         0.980000   Z2=       60.000000              CIEXP=         1.000000
   R=         0.035555   Z3=      128.000000              BYEAR=            1979
  DF=         1.000000   Z4=        0.0          Z5=          64.000000   Z6=          0.0

   CALCULATED VALUES           KG           SUM TO  1.2.3.1                   $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                               0.0

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                           363.159

 #RM =T / M                                                                     1.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                                 0.971

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                719.661


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3            324.472

 CIPS=CTB*Z4/Z2                                                                  0.0

     CRCI  =CTB  X R                                                            11.537
          PRE-IOC  CRCI =CRCI X Z6                                               0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                        11.537

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                               11.537

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0        0.011496    0.0
     SEE 1.2.2.1.1 FOR DDT&E.  15 YEAR LIFE.  ONE BMM LOCATED ON SCB FOR TFU.
     1BMM LOCATED ON EACH SATELLITE.  1BMM LOCATED ON SCB TO SUPPORT
     O&M ACTIVITIES FOR 15 SATELLITES.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.3.1.3 PRESSURIZED STORAGE MODULE-PSM

```
                  INPUT PARAMETERS                                    INPUT COEFFICIENTS

    T=      15000.0000       TF=      1.000000          CDCER=          0.0
    M=      15000.0000      O&M=      0.0               CDEXP=          0.0
   CF=         1.000000      Z1=      1.000000          CICER=          0.016069
  PHI=         0.980000      Z2=     60.000000          CIEXP=          1.000000
    R=         0.002222      Z3=      8.000000          BYEAR=             1979
   DF=         1.000000      Z4=      0.0        Z5=          4.000000    Z6=          0.0

   CALCULATED VALUES          KG        SUM TO  1.2.3.1                     $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                            0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                          241.032

#RM =T / M                                                                 1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                             0.971

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                               241.360


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3         232.000

CIPS=CTB*Z4/Z2                                                               0.0

    CRCI   =CTB  X R                                                         0.516
          PRE-IOC  CRCI =CRCI X Z6                                           0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                     0.516

    CO&M   =O&M OR CTB*Z5/Z2/ENYR                                            0.516

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0         0.013734    0.0
    SEE 1.2.1.1.17 FOR DDT&E.  15 YEAR LIFE.  PSM LOCATED ON SCB TO SUPPORT
    TFU MMB ACIVITIES.  FOUR PSM'S (Z5) ON SCB TO SUPPORT SATELLITE O&M
    ACTIVITY FOR OPTION
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.3.1.4 POWER MODULE-PM

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	250.000000	TF=	1.000000	CDCER=	0.0
M=	250.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	2.000000	CICER=	1.287000
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.006666	Z3=	24.000000	BYEAR=	1979
DF=	1.000000	Z4=	0.0	Z5=	12.000000
				Z6=	0.0

CALCULATED VALUES	KW	SUM TO 1.2.3.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			321.750
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			637.602
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			301.152
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			2.007
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			2.007
CO&M =O&M OR CTB*Z5/Z2/ENYR			2.008

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.0 1.100000 0.0
SEE 1.2.2.1.2 FOR DDT&E. 15 YEAR LIFE. PM ON SCB TO SUPPORT TFU MMB
ACTIVITY WITH ONE LOCATED ONMMB. 4 ON SCB AND 8 ON MMB'S FOR SATELLITE
OPTION

```
                ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE   1.2.3.2.1  CREW HABITABILITY MODULE-CHM

                  INPUT PARAMETERS                                      INPUT COEFFICIENTS

     T=       27000.0000       TF=         1.000000          CDCER=          0.0
     M=       27000.0000      O&M=         0.0               CDEXP=          0.0
    CF=           1.000000      Z1=         1.000000          CICER=          0.004411
   PHI=           0.980000      Z2=        60.000000          CIEXP=          1.000000
     R=           0.004444      Z3=        16.000000          BYEAR=             1979
    DF=           1.000000      Z4=         0.0         Z5=         8.000000    Z6=          0.0

     CALCULATED VALUES          KG          SUM TO  1.2.3.2                          $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                                   0.0

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               119.094

  #RM =T / M                                                                        1.000

  E   =1.0 + LOG(PHI) / LOG(2.0)                                                    0.971

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                    119.256


  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               112.666

  CIPS=CTB*Z4/Z2                                                                      0.0

     CRCI  =CTB  X R                                                                  0.501
           PRE-IOC  CRCI =CRCI X Z6                                                   0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                             0.501

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                     0.501

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE       0.0         0.003770    0.0
     SEE 1.2.2.2.1 FOR DDT&E.  15 YEAR LIFE.  CHM LOCATED ON MMB FOR TFU.
     1 CHM ON EACH MMB TO SUPPORT O&M FOR OPTION
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.3.2.2 CONSUMABLES LOGISTICS MODULE-CLM

```
                 INPUT PARAMETERS                                        INPUT COEFFICIENTS

   T=        5000.00000     TF=         1.000000             CDCER=          0.0
   M=        5000.00000    O&M=         0.0                  CDEXP=          0.0
  CF=           1.000000    Z1=         1.000000             CICER=          0.016380
 PHI=           0.980000    Z2=        60.000000             CIEXP=          1.000000
   R=           0.004444    Z3=        16.000000             BYEAR=             1979
  DF=           1.000000    Z4=         0.0          Z5=          8.000000   Z6=          0.0

   CALCULATED VALUES            KG          SUM TO  1.2.3.2                       $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                   0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                81.900

#RM =T / M                                                                        1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                    0.971

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                     82.011

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                77.479

CIPS=CTB*Z4/Z2                                                                      0.0

    CRCI  =CTB  X R                                                                 0.344
          PRE-IOC  CRCI =CRCI X Z6                                                  0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                            0.344

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                    0.344

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0        0.014000     0.0
    SEE 1.2.2.2.2 FOR DDT&E.  15 YEAR LIFE.  CLM LOCATED ON MMB
```

```
        ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE   1.2.3.3.1   SATELLITE OPERATIONS CREW - SCB

              INPUT PARAMETERS                                      INPUT COEFFICIENTS

   T=         8.000000    TF=       1.000000        CDCER=          0.0
   M=         1.000000    O&M=      0.0             CDEXP=          0.0
  CF=         1.000000    Z1=       1.000000        CICER=          0.073008
 PHI=         1.000000    Z2=      60.000000        CIEXP=          1.000000
   R=         0.0         Z3=     120.000000        BYEAR=             1979
  DF=         1.000000    Z4=       0.0        Z5=     120.000000   Z6=          0.0

 CALCULATED VALUES     PERSON      SUM TO  1.2.3.3                         $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                            0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                          0.073

#RM =T / M                                                                8.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                            1.000

CTFU=(CLRM / E)X((#RM X  Z1+.5)XX(E) -0.5XX(E))                              0.584


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))      ) / Z3              0.584

CIPS=CTB*Z4/Z2                                                               0.0

   CRCI  =CTB  X R                                                           0.0
          PRE-IOC  CRCI =CRCI X Z6                                           0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                     0.0

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                              0.039

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0       0.062400    0.0
   8 PERSON CREW STATIONED ON SCB FOR TFU.  CREW SERVICES 2 MOBILE
   MAINTENANCE BASES (MMB'S).  60 SATELLITE OPTION REQUIRES 4 SCB CREWS.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.3.3.2 SATELLITE OPERATIONS CREW - MMB

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	30.000000	TF=	1.000000			CDCER=	0.0		
M=	1.000000	O&M=	0.0			CDEXP=	0.0		
CF=	1.000000	Z1=	1.000000			CICER=	0.073008		
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000		
R=	0.0	Z3=	240.000000			BYEAR=	1979		
DF=	1.000000	Z4=	0.0	Z5=	240.000000			Z6=	0.0

CALCULATED VALUES	PERSONS	SUM TO 1.2.3.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.073
#RM =T / M	30.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			2.190
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			2.190
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.292

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.0 0.062400 0.0
30 PERSON CREW ON EACH MOBILE MAINTENANCE BASE (MMB) ONE MMB SERVICES
2 SATELLITES EVERY 90 DAYS ON THE AVERAGE. 8MMBS REQUIRED FOR
OPERATIONS OVER TERM

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.2.3.3.3 CREW PROVISIONS - SCB

```
                 INPUT PARAMETERS                                      INPUT COEFFICIENTS

   T=      10368.0000      TF=        1.000000            CDCER=        0.0
   M=          1.000000   O&M=        0.0                 CDEXP=        0.0
  CF=          1.000000    Z1=        1.000000            CICER=        0.000026
 PHI=          1.000000    Z2=       60.000000            CIEXP=        1.000000
   R=          0.0         Z3=      120.000000            BYEAR=           1979
  DF=          1.000000    Z4=        0.0          Z5=       120.000000     Z6=         0.0

  CALCULATED VALUES        CREW       SUM TO  1.2.3.3                              $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                    0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                  0.000

#RM =T / M                                                                      10368.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                       1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                       0.267

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                  0.267

CIPS=CTB*Z4/Z2                                                                       0.0

    CRCI  =CTB  X R                                                                  0.0
          PRE-IOC  CRCI =CRCI X Z6                                                   0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                             0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                     0.018

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0         0.000022     0.0
    $26/KG AT 3.6 KG/PERSON/DAY. 8 PERSON CREW AT SCB PER 16 SATELLITES.
```

```
              ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE    1.2.3.3.4   O&M CREW PROVISIONS - MMB

                INPUT PARAMETERS                                   INPUT COEFFICIENTS

   T=    38880.0000        TF=          1.000000           CDCER=          0.0
   M=       1.000000      O&M=          0.0                CDEXP=          0.0
  CF=       1.000000       Z1=          1.000000           CICER=          0.000026
 PHI=       1.000000       Z2=         60.000000           CIEXP=          1.000000
   R=       0.0            Z3=        240.000000           BYEAR=              1979
  DF=       1.000000       Z4=          0.0         Z5=       240.000000    Z6=         0.0

  CALCULATED VALUES       CREW         SUM TO  1.2.3.3                           $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               0.000

#RM =T / M                                                                   38880.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                   1.000

CIFU=(CLRM / E)X((#RM X  Z1+.5)XX(E) -0.5XX(E))                                   1.001


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               1.001

CIPS=CTB*Z4/Z2                                                                    0.0

    CRCI  =CTB  X R                                                               0.0
          PRE-IOC  CRCI =CRCI X Z6                                                0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                          0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                  0.133

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0        0.000022    0.0
    $26/KG AT 3.6 KG/PERSON/DAY.  30 PERSON CREW ON EACH MMB. MMB SERVICES
    2 SATELLITES EVERY 90DAYS ON THE AVERAGE. OPTION REQUIRES SERVICES FOR
    8 MMB'S.
```

1.3 TRANSPORTATION

This element of the SPS program covers all space transportation system vehicle and operational requirements needed to accommodate the delivery of materials and personnel to orbit. The requirement supports SPS satellite system fabrication, assembly, test and evaluation plus the replacement and operations/maintenance of space systems. Estimates of cost and cost analyses in this section cover transportation systems used to transfer materials and personnel to LEO, LEO to GEO, and within LEO and GEO orbits during space construction and lifetime operation of the satellite system.

Figure 1.3-1 illustrates the Rockwell reference transportation flight operations scenario designed to deliver cargo and personnel to geosynchronous (GEO) orbit for SPS construction. Three SPS unique elements of the system are: the Heavy Life Launch Vehicle (HLLV), the Electric Orbit Transfer Vehicle (EOTV), and the Personnel Orbit Transfer Vehicle (POTV). The HLLV is a two stage parallel burn launch vehicle utilizing LOX/RP in the first stage and LOX/LH_2 in the second stage. Second stage propellants are crossfed from the first stage during first stage burn. These stages take off from a vertical position and land horizontally in a manner similar to that of the Shuttle transportation system. Each HLLV launch can transport a 0.227×10^6 kg (0.500×10^6 lb) payload to low earth orbit (LEO).

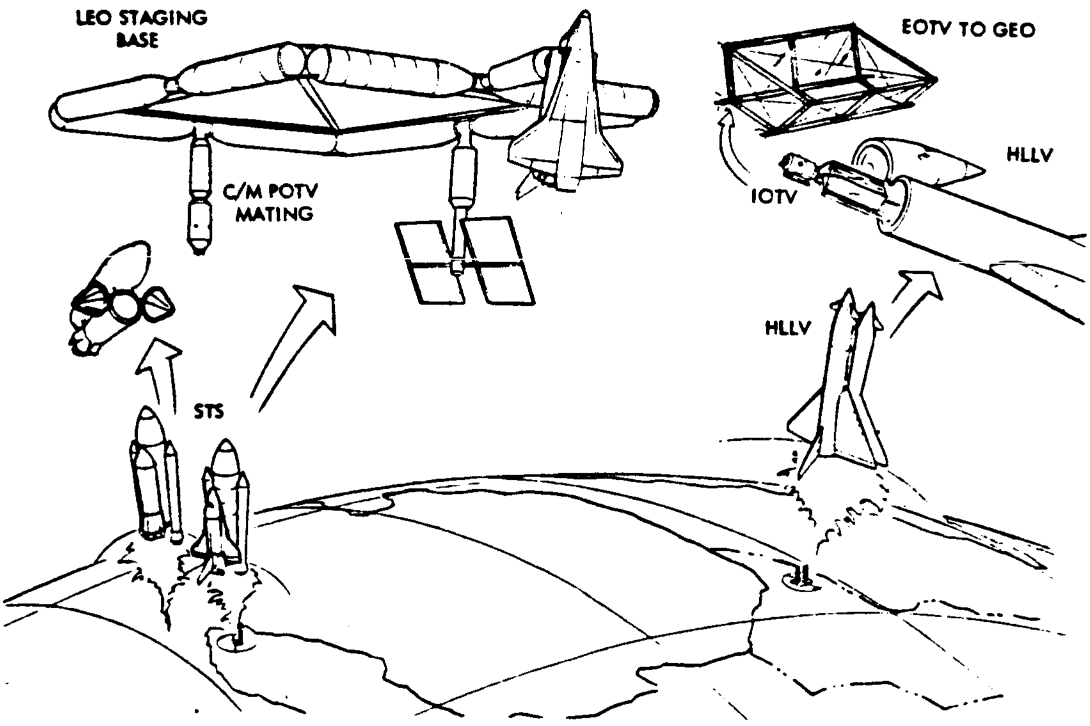


Figure 1.3-1. SPS Transportation System—LEO Operations Operational Program

The second major transportation element is the LEO-to-GEO cargo transfer vehicle, the EOTV. The EOTV consists of a basic solar array structure and electric (ion) thruster arrays by which as much as 6.86 10 kg of cargo can be transferred to a GEO—located construction site. A maximum EOTV load would therefore accommodate approximately 25 HLLV missions. The same EOTV configuration has been retained for all satellite options.

A third vehicle is designed to transport personnel from the LEO staging area to and from the GEO site. The vehicle consists of a single chemical propulsion stage and a separable crew module. The propulsion element is refueled in GEO for return to LEO. Acceleration and operation restrictions are similar to those imposed for manned space vehicles.

Transportation requirements and concepts for SPS vary as a function of program phase. During the research/technology phase (1981=1987), the baseline Space Shuttle is planned to conduct sortie missions. Its use will continue through the period of space activities to prove the concept by ultimate construction of a pilot power plant. A growth vehicle will use solid rocket boosters to transfer personnel to orbit in preparation for LEO base and SPS construction base facilities. An STS derivative vehicle will consist of a solid rocket booster and a special payload/engine module (replacing the orbiter) to serve as a cargo carrier. The SPS VTO/HL HLLV is scheduled later in the program for use in EOTV construction and SPS fabrication/operations.

During satellite construction phases, geosynchronous orbit is the eventual destination of SPS construction materials/equipment, personnel, and supplies. The crews will be transported from earth to LEO by the SPS VTO/HL HLLV containing the personnel module (PM) where the PM will then be carried to GEO by the POTV. Cargo will be delivered to LEO by the SPS VTO/HL-HLLV configuration, transferred to the EOTV by IOTV's, transported to GEO by the EOTV, and off-loaded by IOTV's. Additional detail on the individual vehicles is presented in later subsections.

Mass-to-orbit cost requirements for construction, propellant, and operations/maintenance activities were established in accordance with the mission profile and build schedule of required SPS satellite options with a first unit (TFU) by the end of year 2000. These calculations are based on a round trip vehicle life as shown in Table 1.3-1.

Vehicle flight and fleet requirements to build the first (TFU) Rockwell SPS reference configuration satellite are identified in Table 1.3-2. These calculations were based on the mass to LEO and to GEO for personnel, materials, and supplies needed to construct the satellite and EOTV vehicle reflecting mission timelines, turnaround schedules, and flight profiles.

Transportation vehicle and flight requirements for the Rockwell reference configuration are identified in Table 1.3-3 by construction (Pre-IOC) and operation and maintenance (Post-IOC) categories. These elements of the traffic model were used in calculations of costs associated with fleet requirements for a 60-unit SPS program.

Table 1.3-1. Vehicle Life with Maintenance

VEHICLE	R.T. FLIGHTS PER VEHICLE
SPS VTO/HL HEAVY LIFT LAUNCH VEHICLE (500,000 lb, 227,000 kg)	300
EOTV CARGO (ELECTRIC) ORBIT TRANSFER VEHICLE	20
POTV PERSONNEL ORBIT TRANSFER VEHICLE	100
IOTV INTRA-ORBIT TRANSFER VEHICLE	200

Table 1.3-2. GaAs Reference SPS Concept—TFU Transportation Requirements

	VEHICLE FLIGHTS					
					IOTV	
	PLV (HLLV)	HLLV	POTV	EOTV	LEO	GEO
SATELLITE CONSTRUCTION & MAINT.	5.4	153.3	40	5.1	215	153
CREW CONSUMABLES		6.6		-	7	-
POTV PROPELLANTS		12.7		0.2	13	6
EOTV CONSTRUCTION & MAINTENANCE		32.8		-	33	-
EOTV PROPELLANTS		33.5		-	34	-
IOTV PROPELLANTS		0.6		-	1	1
SCB TO GEO		-		2	-	-
TOTAL FLIGHTS	5	240	40	8	303	160
FLEET	-	5	4	6	2	2

Table 1.3-3. GaAs Reference SPS Concept—Total Transportation Requirements (60 Satellites)

	MASS × 10^6 kg		VEHICLE FLIGHTS					
							IOTV	
	LEO	GEO	PLV (HLLV)	HLLV	POTV	EOTV	LEO	GEO
SATELLITE								
CONSTRUCTION	2087.7	2087.7	111	9,197	1220	306.4	10,741	9,197
OPS & MAINT.	492.2	492.2	34	2,168	324	72.7	2,560	2,168
CREW CONSUMABLES								
CONSTRUCTION	29.9	28.7		132		4.2	132	126
OPS & MAINT.	9.2	7.6		41		1.1	41	34
POTV PROPELLANTS								
CONSTRUCTION	87.9	44.0		387		6.5	387	194
OPS & MAINT.	23.3	11.7		103		1.7	103	52
EOTV CONSTRUCTION								
CONSTRUCTION	19.9	12.4		88		1.8	88	55
OPS & MAINT.	5.0	5.0		22		0.7	22	22
EOTV PROPELLANTS								
CONSTRUCTION	306.0	1.9		1,348		0.3	1,348	8
OPS & MAINT.	73.0	0.8		322		0.1	322	4
IOTV PROPELLANTS								
CONSTRUCTION	7.4	3.2		33		0.5	33	14
OPS & MAINT.	1.8	0.8		8		0.1	8	3
SUMMARY								
CONSTRUCTION	2538.8	2177.9	111	11,185	1220	320	12,729	9,594
OPS & MAINT.	604.5	518.1	34	2,664	324	76	3,056	2,283
TOTAL	3143.3	2696.0	145	13,849	1544	396	15,785	11,877
VEHICLE FLEET								
CONSTRUCTION	-	-	-	38	12	16	112	
OPS & MAINT.	-	-	-	9	3	4	27	
TOTAL	-	-	-	47	15	20	139	

1.3.1 SPS HEAVY-LIFT LAUNCH VEHICLE

The SPS HLLV is shown in Figure 1.3-2 and has a payload capability of 227,000 kg with a vertical takeoff and horizontal landing feature. The SPS HLLV is used to bring space construction and support equipment payloads, satellite system hardware, OTVs, consumables and crew expendables, and propellants from earth to LEO. This element covers SPS HLLV vehicles and operations required to support satellite system assembly and operation during a 30-year period. Ground rules and guidelines applicable to the HLLV are summarized in Table 1.3-4.

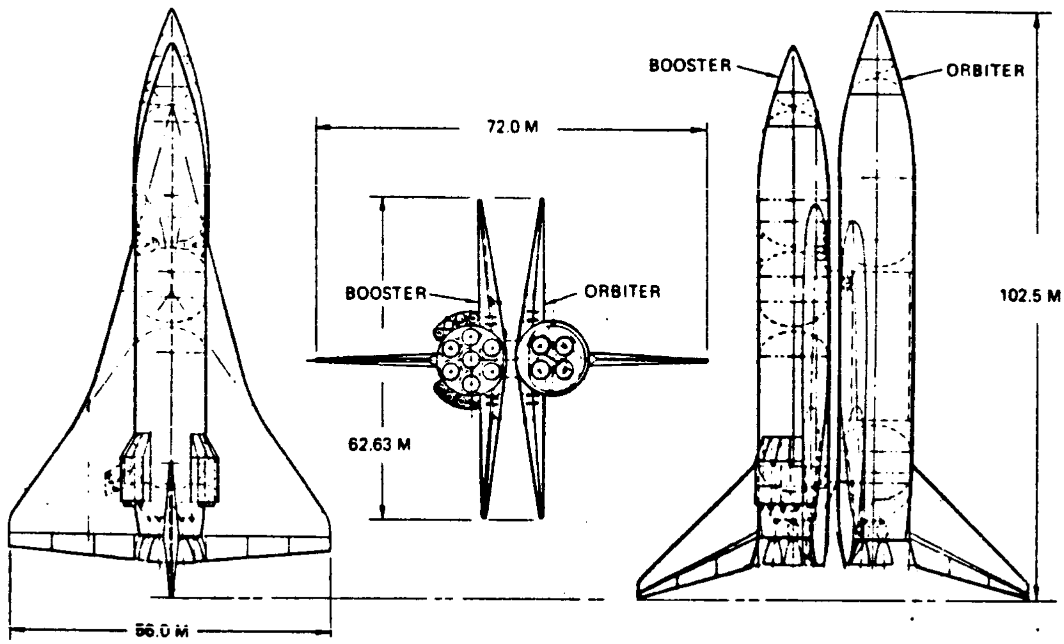


Figure 1.3-2. SPS VTO/VL HLLV System Launch Configuration

1.3.1.1 SPS HLLV FLEET

A total of 47 HLLV vehicles are required to handle mass flow requirements throughout the 60-year SPS program; Thirty-eight vehicle are required for the construction of 60 satellites and 9 vehicles are needed for operation and maintenance during the 30-year satellite lifetime.

Data used in projecting estimates for the HLLV were factored from the NASA/JSC Contract NAS9-15196. Specific changes were made to consider the reference HLLV design configuration: vehicle complexity factors—engines, ablative shield, propellant valves, and system/subsystem design; and the greater mass of the orbiter/booster as compared with current experience and Rockwell Space Shuttle contract work.

Table 1.3-4. HLLV Ground Rules/Assumptions

- Two-stage vertical takeoff/horizontal landing (VTO/HL)
- Flyback capability both stages; ABES, first stage only
- Parallel burn with propellant crossfeed
- LOX/RP first stage; LOX/LH_2 second stage
- High P_c gas generator cycle engine; 1st stage [I_s (VAC) = 352 sec.]
- High P_c staged combustion engine; 2nd stage [I_s (VAC) = 466 sec.]
- Staging velocity—heat sink booster compatible
- Circa 1990 technology base—BAC/MMC weight reduction data
- Orbital parameters—487 km @ 31.6°
- Payload capability—227×10^3 kg up/45 kg down
- Thrust/weight—1.30 liftoff/3.0 max.
- 15% weight growth allowance/0.75% ΔV margin

HLLV capital asset replacements, major overhaul requirements, spares provisioning, and system lifetimes were projected as being the equivalent of 1.5 vehicle replacements for each of the SPS fleet vehicles. These calculations amount to a total of 71 RCI vehicle equivalents with an allocation of approximately 57 to pre-IOC activities associated with satellite construction, and about 14 HLLV equivalents chargeable to the O&M activity after IOC.

See Table 1.3.1.1 for SPS HLLV cost computer program tabulations.

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
    TABLE    1.3.1.1     SPS-HLLV FLEET

                    INPUT PARAMETERS                                  INPUT COEFFICIENTS

      T=          1.000000    TF=         1.000000            CDCER=       10062.0000
      M=          1.000000    O&M=        0.0                 CDEXP=           1.000000
     CF=          1.000000    Z1=         5.000000            CICER=        2340.00000
    PHI=          0.950000    Z2=        60.000000            CIEXP=           1.000000
      R=          0.039444    Z3=       118.000000            BYEAR=              1979
     DF=          1.000000    Z4=        38.000000     Z5=           9.000000     Z6=          0.808510

    CALCULATED VALUES         SET          SUM TO  1.3.1                            $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                                   10062.000

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                  2340.000

 #RM =T / M                                                                          1.000

 E    =1.0 + LOG(PHI) / LOG(2.0)                                                     0.926

 CIFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                      10921.242

 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                 1771.045

 CIPS=CTB*Z4/Z2                                                                      1121.661

    CRCI   =CTB  X R                                                                    69.857
           PRE-IOC  CRCI =CRCI X Z6                                                     56.480
           POST-IOC CRCI =CRCI X (1.0-Z6)                                               13.377

    CO&M   =O&M OR CTB*Z5/Z2/ENYR                                                        8.855

 COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE  8600.00000  2000.00000      0.0
    118 VEHICLES IN FLEET=71 RCI, 38 CONSTR RELATED, 9 O&M RELATED RCI AT
    1.5 VEHICLE EQUIVALENTS TO KEEP 1HLLV OPERATIONAL
```

1.3.1.2 SPS HLLV OPERATIONS

This element includes necessary vehicle operations (user charge per flight including payload integration) required to support the SPS program. The HLLV has a lifetime capability of 300 flights.

There is a total of 13,849 roundtrip flights required to support the 60-year program, where approximately 227,000 kg is delivered per flight. These are grouped into a total of 11,185 flights for construction and 2664 flights for operations and maintenance. The TFU requires a total of 245 flights to carry the necessary mass to orbit. On the average of 60 satellites, approximately 186 flights are needed for satellite construction and 44 flights are required for operations and maintenance per satellite over the 30-year operational period.

The projected cost per HLLV flight is based on contract data (reference NAS9-15196) that was factored and revised to arrive at a propellant, payload integration, and supporting operational cost by evaluation against such things as propellant costs versus HLLV requirements. See Table 1.3.1.2.

```
                 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE   1.3.1.2     SPS-HLLV OPERATIONS (VTO-HL)

              INPUT PARAMETERS                                      INPUT COEFFICIENTS

   T=        1.000000    TF=       1.000000          CDCER=         0.0
   M=        1.000000   O&M=       0.0               CDEXP=         0.0
  CF=        1.000000    Z1=     245.000000          CICER=         2.901599
 PHI=        1.000000    Z2=      60.000000          CIEXP=         1.000000
   R=        0.0         Z3=   13849.0000            BYEAR=            1979
  DF=        1.000000    Z4=   11185.0000     Z5=      2664.00000      Z6=          0.807640

  CALCULATED VALUES     FLIGHT        SUM TO  1.3.1                              $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               2.902

#RM =T / M                                                                     1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                 1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                  710.892

CIB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3               2.902

CIPS=CTB*Z4/Z2                                                                  540.906

   CRCI  =CTB  X R                                                              0.0
         PRE-IOC  CRCI =CRCI X Z6                                               0.0
         POST-IOC CRCI =CRCI X (1.0-Z6)                                         0.0

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                 4.294

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0        2.480000    0.0
```

1.3.2 CARGO ORBITAL TRANSFER VEHICLE (COTV)

This element includes the COTV vehicle and operations required to support satellite system assembly and operation. Included is the LEO-to-GEO transfer of space construction and support equipment, satellite system hardware, spares, and propellants required throughout satellite lifetime, plus O&M materials.

An electric orbital transfer vehicle (EOTV) is employed as the primary transportation element for SPS cargo from LEO to GEO. The vehicle configuration defined to accomplish this mission phase has a high specific impulse thruster that utilizes the same power source and construction techniques as the SPS. The concept is shown in Figure 1.3-3 and has a payload capability of 6.814×10^6 kg (equivalent to 30 HLLV payloads) with a six-month roundtrip time per flight. The solar array consists of two "bays" of the SPS, electric argon-ion engine arrays, and the requisite propellant storage and power conditioning equipment. The vehicle configuration, payload capability, and "trip time" have been established on the basis of expected overall SPS performance characteristics.

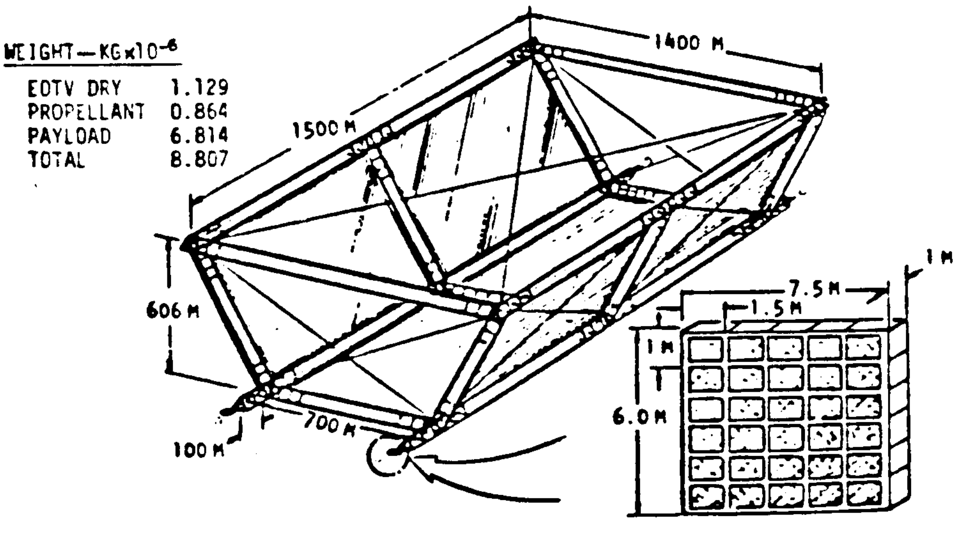


Figure 1.3-3. Rockwell EOTV Reference Update—1980

COTV fleet procurement and operations are detailed in Sections 1.3.2.1 and 1.3.2.2, respectively.

1.3.2.1 COTV FLEET

This element of the WBS covers COTV fleet requirements in support of construction and operational phases of the SPS program. The COTV structural configuration is equivalent to the design/profile of a satellite bay except it is equipped with thruster arrays and an attitude control system. It has a dry weight of 903,000 kg with subsystem masses as shown in Table 1.3-5.

Table 1.3-5. EOTV Weight Summary (GaAs)

ITEM DESCRIPTION	SUBTOTAL MASS ($kg \times 10^6$)	TOTAL MASS ($kg \times 10^6$)
STRUCTURE		0.106
PRIMARY STRUCTURE	0.041	
SECONDARY STRUCTURE	0.056	
MECHANISMS	0.006	
TRACKS AND ACCESSWAYS	0.003	
SOLAR BLANKETS (949,000 m^2)		0.229
CONCENTRATORS (1,823,200 m^2)		0.033
POWER DISTRIBUTION & CONDITIONING		0.422
SWITCH GEAR & REGULATORS	0.0027	
LOW-VOLTAGE CONVERTERS	0.0003	
CONDUCTORS AND INSULATION	0.265	
BATTERIES (INCL. ACS REQMTS)	0.152	
BATTERY PD&C (INCL. ACS REQMTS)	0.002	
PROPULSION & ACS SYSTEM		
ACS HARDWARE		0.111
THRUSTERS (120), 1 m x 1.5 m	0.022	
TANKS & PROPELLANT LINES	0.086	
ATTITUDE REF. SYSTEM	0.001	
POWER PROCESSING EQUIPMENT	0.002	
INFORMATION MANAGEMENT		0.002
GRAND TOTAL		0.903
WITH 25% GROWTH		1.129
ARGON PROPELLANT PER EOTV R.T. FLIGHT		0.864

The thruster array consists of 1.0 m by 1.5 m rectangular thrusters at four locations. A specific impulse of 7900/second results in a high thrust capable of handling large payloads for the array power output. The total attitude control system and thruster array mass is equal to 119,000 kg (dry) per EOTV (Table 1.3-6).

Table 1.3-6. EOTV ACS Mass Summary

ITEM DESCRIPTION	MASS (kg)
THRUSTERS (120) 1 METER BY 1.5 METERS	22,000
PROPELLANT TANKS AND LINES	86,000
ACS CONDUCTORS & INSULATION	6,000
ATTITUDE REFERENCE SYSTEM	1,000
THRUSTER GIMBALS AND MOUNTING	2,000
POWER PROCESSING EQUIPMENT	2,000
TOTAL (DRY)	119,000
PROPELLANT (ARGON)	864,000

EOTV cost estimates were developed from those of the main satellite because of design and system similarities. Adjustment factors for development and learning were used to reflect the period of time and technology state of these requirements versus those for the satellite in coming years. Replacement capital investment factors were calculated on the average of a 5-6% vehicle attrition. Table 1.3-7 identifies COTV elements/systems costed.

Table 1.3-7. EOTV Cost Elements

WBS Element	Description
1.3.2.1.1	Primary Structure
1.3.2.1.2	Secondary Structure
1.3.2.1.3	Mechanisms
1.3.2.1.4	Tracks and Access Ways
1.3.2.1.5	Concentrator
1.3.2.1.6	Solar Blanket
1.3.2.1.7	Switch Gear and Regulators
1.3.2.1.8	Low-Voltage Converters
1.3.2.1.9	Conductors and Insulation
1.3.2.1.10	Batteries
1.3.2.1.11	Battery PD&C
1.3.2.1.12	ACS Hardware—COTV
1.3.2.1.13	Information Management and Control

```
              ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.3.2.1.1   PRIMARY STRUCTURE

                   INPUT PARAMETERS                                   INPUT COEFFICIENTS

      T=       41000.0000      TF=         1.000000         CDCER=          0.026910
      M=         15.000000     O&M=        0.0              CDEXP=          0.800000
     CF=          1.000000     Z1=         6.000000         CICER=          0.000058
    PHI=          1.000000     Z2=        60.000000         CIEXP=          1.000000
      R=          0.0          Z3=        20.000000         BYEAR=              1979
     DF=          0.050000     Z4=        16.000000   Z5=         4.000000   Z6=          0.800000

     CALCULATED VALUES         KG          SUM TO  1.3.2.1                  $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                          12.004

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                         0.001

  #RM =T / M                                                      2733.333

  E   =1.0 + LOG(PHI) / LOG(2.0)                                      1.000

  CTFU=(CLRM / E)X((#RM X  Z1+.5)XX(E) -0.5XX(E))                            14.391


  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3            2.398

  CIPS=CTB*Z4/Z2                                                              0.640

     CRCI  =CTB  X R                                                          0.0
           PRE-IOC  CRCI =CRCI X Z6                                           0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                     0.0

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                             0.005

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.023000    0.000050    0.C
     COMPOSITE MATERIAL.  20 EOTV FLEET.  16 FOR CONSTRUCTION.  4 FOR O&M
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.3.2.1.2 SECONDARY STRUCTURE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	56000.0000	TF=	0.038263	CDCER=	0.182520
M=	5.000000	O&M=	0.0	CDEXP=	0.511000
CF=	0.800000	Z1=	6.000000	CICER=	0.118170
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.355000
R=	0.001111	Z3=	22.000000	BYEAR=	1979
DF=	0.100000	Z4=	16.000000	Z5=	4.000000
				Z6=	0.800000

CALCULATED VALUES	KG SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		12.015
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.006
#RM =T / M	11200.000	
E =1.0 + LOG(PHI) / LOG(2.0)	0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		320.645
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		51.455
CIPS=CTB*Z4/Z2		13.721
CRCI =CTB X R		0.057
PRE-IOC CRCI =CRCI X Z6		0.046
POST-IOC CRCI =CRCI X (1.0-Z6)		0.011
CO&M =O&M OR CTB*Z5/Z2/ENYR		0.114

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.156000 0.101000 0.0
INCLUDES THRUSTER STRUCTURE (2000 KG) IN ADDITION TO EOTV BAY SECONDARY STRUCTURE NEEDS.

```
                ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
  TABLE    1.3.2.1.3   MECHANISMS - EDTV

                  INPUT PARAMETERS                                    INPUT COEFFICIENTS

      T=        6000.00000     TF=         1.000000          CDCER=          0.182520
      M=         110.000000    O&M=        0.0               CDEXP=          0.511000
     CF=           1.000000    Z1=         6.000000          CICER=          0.000894
    PHI=           1.000000    Z2=        60.000000          CIEXP=          0.950000
      R=           0.0         Z3=        20.000000          BYEAR=              1979
     DF=           0.300000    Z4=        16.000000    Z5=         4.000000   Z6=           0.800000

     CALCULATED VALUES          KG          SUM TO  1.3.2.1                   $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 8.409

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               0.078

 #RM =T / M                                                                   54.545

 E   =1.0 + LOG(PHI) / LOG(2.0)                                                1.000

 CTFU=(CLRM / E)X((#RM X  Z1+.5)XX(E) -0.5XX(E))                                  25.440


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               4.240

 CIPS=CTB*Z4/Z2                                                                    1.131

    CRCI  =CTB  X R                                                                0.0
          PRE-IOC  CRCI =CRCI X Z6                                                 0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                           0.0

    CO&M  =O&M OR CTR*Z5/Z2/ENYR                                                   0.009

 COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.156000    0.000764    0.0
    TENSION DEVICES, PAYLOAD LATCHES, THRUSTER GIMBALS
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.3.2.1.4 TRACKS AND ACCESSWAYS

INPUT PARAMETERS				INPUT COEFFICIENTS			
T=	3000.00000	TF=	1.000000	CDCER=	0.0		
M=	100.000000	O&M=	0.0	CDEXP=	0.0		
CF=	1.000000	Z1=	6.000000	CICER=	0.000058		
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000		
R=	0.0	Z3=	20.000000	BYEAR=	1979		
DF=	1.000000	Z4=	16.000000	Z5=	4.000000	Z6=	0.800000

CALCULATED VALUES	KG	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.006
#RM =T / M		30.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.053
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.175
CIPS=CTB*Z4/Z2			0.047
CRCI =CTB X R			0.0
PRE-IOC CRCI =CRCI X Z6			0.0
POST-IOC CRCI =CRCI X (1.0-Z6)			0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.000

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.0 0.000050 0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.3.2.1.5 CONCENTRATOR

```
                 INPUT PARAMETERS                                        INPUT COEFFICIENTS

    T=    1823200.00        TF=          1.000000         CDCER=             0.031590
    M=     474500.000       O&M=         0.0              CDEXP=             0.394000
   CF=          1.000000    Z1=          6.000000         CICER=             0.000004
  PHI=          0.980000    Z2=         60.000000         CIEXP=             0.950000
    R=          0.001111    Z3=         22.000000         BYEAR=                 1979
   DF=          0.020000    Z4=         16.000000    Z5=          4.000000    Z6=          0.800000

   CALCULATED VALUES        SQ M          SUM TO  1.3.2.1                     $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                               1.981

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                             0.866

 #RM =T / M                                                                   3.842

 E    =1.0 + LOG(PHI) / LOG(2.0)                                              0.971

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                 18.716


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3               3.010

 CIPS=CTB*Z4/Z2                                                                  0.803

     CRCI  =CTB  X R                                                             0.003
             PRE-IOC  CRCI =CRCI X Z6                                            0.003
             POST-IOC CRCI =CRCI X (1.0-Z6)                                      0.001

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                0.007

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.027000    0.000003    0.0
     DENSITY= .0181 KG PER SQ METER.  MASS 33000 KG
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.3.2.1.6 SOLAR BLANKET

```
                  INPUT PARAMETERS                                    INPUT COEFFICIENTS

   T=      949000.000      TF=        1.000000           CDCER=          0.188838
   M=       18250.0000    O&M=        0.0                CDEXP=          0.394000
  CF=           1.200000   Z1=        6.000000           CICER=          0.000078
 PHI=           0.990000   Z2=       60.000000           CIEXP=          1.000000
   R=           0.001111   Z3=       22.000000           BYEAR=             1979
  DF=           0.500000   Z4=       16.000000   Z5=          4.000000    Z6=          0.800000

   CALCULATED VALUES        SQ M        SUM TO  1.3.2.1                          $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 39.058

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                1.717

#RM =T / M                                                                      52.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                   0.986

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                   499.988


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               81.786

CIPS=CTB*Z4/Z2                                                                    21.810

    CRCI  =CTB  X R                                                                0.091
          PRE-IOC  CRCI =CRCI X Z6                                                 0.073
          POST-IOC CRCI =CRCI X (1.0-Z6)                                           0.018

    CO&M  =O&M OR CTR*Z5/Z2/ENYR                                                   0.182

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.161400     0.000067     0.0
    NASA/ADL NAS 9-15294 MARCH 1978
    $67/SQ M (1977 DOLLARS).  MTLS $33/SQ M & PROCESSING $34/SQ M.  DENSITY=
    0.2525 KG PER SQ M.  2 SECTIONS, 26 PANELS EACH.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.3.2.1.7 SWITCHGEAR AND REGULATORS

```
              INPUT PARAMETERS                                 INPUT COEFFICIENTS

     T=    4700.00000     TF=      1.000000          CDCER=          0.184860
     M=      52.000000    O&M=     0.0               CDEXP=          0.297000
    CF=       1.500000    Z1=      6.000000          CICER=          0.000468
   PHI=       0.950000    Z2=     60.000000          CIEXP=          1.000000
     R=       0.001111    Z3=     22.000000          BYEAR=              1979
    DF=       0.500000    Z4=     16.000000    Z5=        4.000000   Z6=          0.800000

    CALCULATED VALUES          KG          SUM TO  1.3.2.1                 $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                           2.781

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                         0.037

 #RM =T / M                                                                90.385

 E   =1.0 + LOG(PHI) / LOG(2.0)                                             0.926

 CTFU=(CLRM / E)X((#RM X  Z1+.5)XX(E) -0.5XX(E))                            13.407


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))           ) / Z3       2.031

 CIPS=CTB*Z4/Z2                                                              0.542

     CRCI  =CTB  X R                                                         0.002
           PRE-IOC  CRCI =CRCI X Z6                                          0.002
           POST-IOC CRCI =CRCI X (1.0-Z6)                                    0.000

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                            0.005

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.158000    0.000400    0.0
     1 BAY (2 SECTIONS).  26 SETS PER SECTION.  INCLUDES 2000 KG FOR ACS
     POWER PROCESSING EQUIPMENT
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.3.2.1.8 LO-VOLTAGE CONVERTERS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	300.000000	TF=	1.000000	CDCER=	0.184860
M=	5.770000	O&M=	0.0	CDEXP=	0.297000
CF=	1.200000	Z1=	6.000000	CICER=	0.000468
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.001111	Z3=	22.000000	BYEAR=	1979
DF=	1.000000	Z4=	16.000000	Z5= 4.000000	Z6= 0.800000

CALCULATED VALUES	KG	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			1.207
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.003
#RM =T / M	51.993		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.011
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.168
CIPS=CTB*Z4/Z2			0.045
CRCI =CTB X R			0.000
PRE-IOC CRCI =CRCI X Z6			0.000
POST-IOC CRCI =CRCI X (1.0-Z6)			0.000
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.000

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.158000 0.000400 0.0

1 BAY (2 SECTIONS) WITH 26 SETS OPERATING PER SECTION

```
                 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
      TABLE   1.3.2.1.9  CONDUCTORS AND INSULATION

                   INPUT PARAMETERS                                           INPUT COEFFICIENTS

      T=      265000.000       TF=         1.000000          CDCER=          0.184860
      M=        5100.00000     U&M=        0.0               CDEXP=          0.297000
     CF=           1.000000    Z1=         6.000000          CICER=          0.000005
    PHI=           1.000000    Z2=        60.000000          CIEXP=          1.000000
      R=           0.0         Z3=        20.000000          BYEAR=              1979
     DF=           0.100000    Z4=        16.000000    Z5=           4.000000     Z6=          0.800000

     CALCULATED VALUES         KG        SUM TO  1.3.2.1                              $,MILLIONS

   CD=CDCER X (T X DF)XX(CDEXP) X CF                                                   3.807

   CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                 0.024

   #RM =T / M                                                                      51.961

   E    =1.0 + LOG(PHI) / LOG(2.0)                                                  1.000

   CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                      7.441

   CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                 1.240

   CIPS=CTB*Z4/Z2                                                                      0.331

      CRCI   =CTB   X R                                                                0.0
             PRE-IOC  CRCI =CRCI X Z6                                                  0.0
             POST-IOC CRCI =CRCI X (1.0-Z6)                                            0.0

      CO&M   =O&M OR CTB*Z5/Z2/ENYR                                                    0.003

   COMMENTS
      1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.158000    0.000004    0.0
      5920 KG ALLOCATED TO ACS.  1 BAY (2 SECTIONS) 26 SETS PER SECTION
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.3.2.1.10 BATTERIES

```
                 INPUT PARAMETERS                              INPUT COEFFICIENTS

   T=     152000.000      TF=        1.000000        CDCER=          0.040145
   M=      50.000000     O&M=        0.0             CDEXP=          0.734000
  CF=       1.200000      Z1=        6.000000        CICER=          0.030380
 PHI=       1.000000      Z2=       60.000000        CIEXP=          0.241000
   R=       0.011111      Z3=       40.000000        BYEAR=              1979
  DF=       0.003000      Z4=       16.000000   Z5=        6.600000   Z6=         0.800000

   CALCULATED VALUES          KG        SUM TO  1.3.2.1                     $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                               4.310

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                             0.094

#RM =T / M                                                                3040.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                               1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                               1707.046

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3          284.508

CIPS=CTB*Z4/Z2                                                                75.869

   CRCI  =CTB  X R                                                             3.161
          PRE-IOC  CRCI =CRCI X Z6                                             2.529
          POST-IOC CRCI =CRCI X (1.0-Z6)                                       0.632

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                1.043
```

COMMENTS

1978 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.037000 0.028000 0.0
INCLUDES BATTERIES FOR ACS. CF CONSIDERS SODIUM CHLORIDE VERSUS DATA BASE.
15 YEAR LIFE. CO&M COVERS 4 VEHICLE BATTERY SETS ASSOC. WITH O&M ACTIVITIES PLUS
2.2 EQUIVALENTS FOR $412300 ANNUAL MAINT. SEE 1.1.1.4.5 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.3.2.1.11 BATTERY PD&C

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	2000.00000	TF=	1.000000	CDCER=	0.057505
M=	250.000000	O&M=	0.0	CDEXP=	0.890000
CF=	1.000000	Z1=	6.000000	CICER=	0.013020
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.859000
R=	0.001666	Z3=	23.000000	BYEAR=	1979
DF=	0.100000	Z4=	16.000000	Z5= 4.000000	Z6= 0.800000

CALCULATED VALUES	KG	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			6.421
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.494
#RM =T / M			8.000
E =1.0 + LOG(PHI) / LOG(2.0)			1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			71.727
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			11.954
CIPS=CTB*Z4/Z2			3.188
CRCI =CTB X R			0.020
PRE-IOC CRCI =CRCI X Z6			0.016
POST-IOC CRCI =CRCI X (1.0-Z6)			0.004
CO&M =O&M OR CTP*Z5/Z2/ENYR			0.027

COMMENTS

1978 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.053000 0.012000 0.0

INCLUDES PD&C FOR ACS BATTERIES

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.3.2.1.12 ACS HARDWARE-COTV

INPUT PARAMETERS					INPUT COEFFICIENTS			
T=	109000.000	TF=	0.300000		CDCER=	1.312739		
M=	908.000000	O&M=	0.0		CDEXP=	0.190000		
CF=	1.000000	Z1=	6.000000		CICER=	0.066690		
PHI=	0.980000	Z2=	60.000000		CIEXP=	0.729000		
R=	0.001111	Z3=	22.000000		BYEAR=	1979		
DF=	0.300000	Z4=	16.000000	Z5=	4.000000		Z6=	0.800000

CALCULATED VALUES	KG	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			9.461
CLRM=CICER X (M)XX(CIEXP) X CF X TF			2.868
#RM =T / M		120.044	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CIFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1756.297
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			281.874
CIPS=CTB*Z4/Z2			75.166
CRCI =CTB X R			0.313
PRE-IOC CRCI =CRCI X Z6			0.251
POST-IOC CRCI =CRCI X (1.0-Z6)			0.063
CO&M =O&M OR CTB*Z5/Z2/ENYR			0.626

COMMENTS
1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 1.122000 0.057000 0.0
INCLUDES 120 THRUSTERS 1M BY 1.5M; TANKS PROPELLANT LINES, AND ATTITUDE
REFERENCE SYSTEM

```
                 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.3.2.1.13 INFO. MGMT. AND CONTROL

                  INPUT PARAMETERS                                  INPUT COEFFICIENTS

     T=         2000.00000      TF=        1.000000        CDCER=          0.740610
     M=          500.000000     L&M=       0.0             CDEXP=          0.521000
    CF=            1.000000     Z1=        6.000000        CICER=          0.201240
   PHI=            1.000000     Z2=       60.000000        CIEXP=          0.535000
     R=            0.001111     Z3=       22.000000        BYEAR=             1979
    DF=            0.500000     Z4=       16.000000   Z5=        4.000000     Z6=           0.800000

     CALCULATED VALUES          $         SUM TO   1.3.2.1                   $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                            27.076

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                           5.593

 #RM =T / M                                                               4.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                           1.000

 CTFU=(CLRM / E)X((#RM X  Z1+.5)XX(E) -0.5XX(E))                             134.238


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3            22.373

 CIPS=CTB*Z4/Z2                                                                5.966

     CRCI   =CTB  X R                                                          0.025
            PRE-IOC  CRCI =CRCI X Z6                                           0.020
            POST-IOC CRCI =CRCI X (1.0-Z6)                                     0.005

     CO&M   =O&M OR CTB*Z5/Z2/ENYR                                             0.050

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE    0.633000   0.172000   0.0
     COVERS ALL IMS ON EOTV
```

1.3.2.2 COTV OPERATIONS

Necessary vehicle operations (user charge per flight including payload integration) are included in this element.

The flight life of the EOTV is estimated at 20 roundtrips from LEO to GEO. Three-hundred twenty flights are required for the construction of 60 satellites and an additional 72 flights will maintain operations of a satellite for the 30-year period. Eight flights are required to build the first satellite.

Calculations used in this cost estimate are presented in Table 1.3.2.2.

```
                  ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
      TABLE    1.3.2.2     CUTV OPERATIONS

                     INPUT PARAMETERS                                    INPUT COEFFICIENTS

      T=          1.000000    TF=          1.000000          CDCER=          0.0
      M=          1.000000    O&M=         0.0               CDEXP=          0.0
     CF=          1.000000    Z1=          8.000000          CICER=          0.942575
    PHI=          1.000000    Z2=         60.000000          CIEXP=          1.000000
      R=          0.0         Z3=        392.000000          BYEAR=              1979
     DF=          1.000000    Z4=        320.000000    Z5=        72.000000     Z6=        0.816330

     CALCULATED VALUES      FLIGHT         SUM TO  1.3.2                              $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                                    0.0

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                  0.943

 #RM  =T / M                                                                      1.000

 E    =1.0 + LOG(PHI) / LOG(2.0)                                                  1.000

 CTFU=(CLRM / E)X((#RM X  Z1+.5)XX(E) -0.5XX(E))                                      7.541


 CTB  =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                 0.943

 CIPS=CTB*Z4/Z2                                                                       5.027

     CRCI   =CTB   X R                                                                0.0
            PRE-IOC   CRCI  =CRCI X Z6                                                0.0
            POST-IOC  CRCI  =CRCI X (1.0-Z6)                                          0.0

     CO&M   =O&M OR CTB*Z5/Z2/ENYR                                                    0.038

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0          0.805620    0.0
     R.T. PROPELLANT PER FLIGHT=870000 KG
```

1.3.3 STS PERSONNEL/CARGO LAUNCH VEHICLE

This element covers STS requirements in support of personnel and cargo transfer to LEO for the fabrication and assembly of the SPS LEO base and space construction fixture (SCB). STS "growth" vehicles will be used as a personnel/cargo launch vehicle after the replacement of solid rocket boosters with liquid rocket boosters and the use of a personnel module within the orbiter as needed. The STS-derivative HLLV (100,000 kg payload to LEO) will require STS modification by adding liquid rocket boosters and the replacement of the orbiter with a cargo carrier and EM. The SPS VTO/HL HLLV (WBS 1.3.1) will be used for subsequent space operations to fabricate EOTV and SPS satellite requirements.

Flight requirements to build the SCB and LEO base are summarized in Table 1.3-8 for the five concepts costed. The size of the SCB needed to fabricate solid-state sandwich concepts will require more flights to transfer the necessary mass.

The frequency of STS growth vehicle flights can be satisfied by the use of one launch vehicle, whereas it is contemplated that two vehicles are needed in the fleet to support derivative (cargo only) requirements. It is also assumed that DDT&E costs for the growth and derivative vehicles will be absorbed by contract activity associated with other supporting programs.

Two personnel modules (PM) are adequate to satisfy mission requirements for the STS growth vehicle. These PMs are included in the costing under WBS 1.3.5.

Costing of the STS cargo carrier and engine module is presented in the next section (1.3.3.1). STS operations costing of growth and derivative vehicles is described in Section 1.3.3.2.

Table 1.3-8. STS Personnel and Cargo Launch Vehicle Flight Requirements (SCB and LEO Base)

SPS CONCEPT	STS GROWTH VEHICLE (PERSONNEL/CARGO)	STS DERIVATIVE VEHICLE (CARGO)	STS CARGO CARRIERS & ENGINE MODULES
• ROCKWELL REFERENCE CR-2 CONFIG. (3-TROUGH/PLANAR/KLYSTRON)—GaAs	72 FLIGHTS	63 FLIGHTS	2
• ROCKWELL MAGNETRON CR-2 CONFIG. (3-TROUGH/PLANAR/MAGNETRON)—GaAs	72 FLIGHTS	63 FLIGHTS	2
• DUAL END-MOUNTED ANTENNA, CR-2 (3-TROUGH/PLANAR/SOLID-STATE)—GaAs	72 FLIGHTS	63 FLIGHTS	2
• SOLID-STATE SANDWICH CR-5 CONFIG. (DUAL ANTENNA AND REFLECTORS)—GaAs	72 FLIGHTS	168 FLIGHTS	2
• SOLID-STATE SANDWICH CR-5 CONFIG. (DUAL ANTENNA AND REFLECTORS)—MBG	72 FLIGHTS	168 FLIGHTS	2
COST ESTIMATE PER FLIGHT	$\$20.25 \times 10^6$	$\$15.19 \times 10^6$	

1.3.3.1 STS CARGO CARRIER AND EM

This element includes a container for cargo and an integral engine module to transport mass to orbit in conjunction with the STS booster as a lift vehicle. The STS HLLV consists of a standard external tank with two liquid rocket boosters. The cargo/engine module replaces the orbiter.

Cost estimates were developed from work under Rockwell's Shuttle Growth Study Contract (NAS8-32015) dated May 1977. DDT&E and hardware costs of the carrier and engine module were identified by comparative evaluation with a Shuttle growth data base. Two cargo/EM carriers are needed for use in building the SCB and LEO base facility. Table 1.3.3.1 presents cost data on this WBS element.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.3.3.1 STS CARGO CARRIER AND EM

```
                 INPUT PARAMETERS                                          INPUT COEFFICIENTS

    T=        1.000000     TF=        1.000000               CDCER=        286.649902
    M=        1.000000     O&M=       0.0                    CDEXP=          1.000000
   CF=        1.000000     Z1=        2.000000               CICER=        310.985840
  PHI=        0.950000     Z2=       60.000000               CIEXP=          1.000000
    R=        0.0          Z3=        2.000000               BYEAR=             1979
   DF=        1.000000     Z4=        2.000000     Z5=              0.0         Z6=          0.0

   CALCULATED VALUES             $          SUM TO  1.3.3                          $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                  286.650

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                310.986

*RM =T / M                                                                       1.000

E    =1.0 + LOG(PHI) / LOG(2.0)                                                  0.926

CTFU=(CLRM / E)X((*RM X Z1+.5)XX(E) -0.5XX(E))                                     607.795

CTB =((CLRM/E)X((*RM X    Z3 + 0.5)XX(E) -0.5XX(E))            ) / Z3              303.897

CIPS=CTB*Z4/Z2                                                                      10.130

    CRCI  =CTB  X R                                                                   0.0
          PRE-IOC  CRCI =CRCI X Z6                                                    0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                              0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                      0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE   245.000000  265.800049    0.0
    2 CARGO/EM CARRIERS FOR USE IN BUILDING SPACE CONSTRUCTION BASE AND LEO
    FACILITY.  NO RCI OR O&M.  DDT&E INCLUDED
```

1.3.3.2 STS OPERATIONS—GROWTH AND DERIVATIVE HLLV

This element covers the cost of necessary vehicle operations required to support the fabrication of the LEO base and the space construction facility.

A total of 135 flights is required of STS growth and derivative HLLVs to transport the required mass to orbit. Seventy-two flights are needed for personnel primarily (STS growth vehicle) and 63 flights of the STS derivative vehicle are required for cargo transfer to LEO.

The cost of operations is based on a per flight estimate established after careful analysis of STS user charges extrapolated to values for use in early SPS operational support and as scaled to expected operational efficiencies and experiences. The per flight cost of STS growth vehicle (personnel) support was established at 75% of STS Shuttle flight costs ($\$27 \times 10^6$) considering liquid rocket booster advantages, advanced design improvements, and operational experience. Costs per STS derivative (cargo only) flights were estimated at 75% of "growth" charges because the mission is unmanned and the orbiter is not required.

Tables 1.3.3.2.1 and 1.3.3.2.2 cover operational cost estimates.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.3.3.2.1 OPERATIONS-STS GROWTH HLLV

```
                INPUT PARAMETERS                                        INPUT COEFFICIENTS

   T=        1.000000     TF=        1.000000            CDCER=         0.0
   M=        1.000000    O&M=        0.0                 CDEXP=         0.0
  CF=        1.000000     Z1=       72.000000            CICER=        20.250000
 PHI=        1.000000     Z2=       60.000000            CIEXP=         1.000000
   R=        0.0          Z3=       72.000000            BYEAR=            1979
  DF=        1.000000     Z4=       72.000000     Z5=         0.0       Z6=          0.0

  CALCULATED VALUES      FLIGHTS        SUM TO  1.3.3.2                        $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                  0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               20.250

*RM =T / M                                                                     1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                 1.000

CTFU=(CLRM / E)X((*RM X Z1+.5)XX(E) -0.5XX(E))                                  1458.000


CTB =((CLRM/E)X((*RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               20.250

CIPS=CTB*Z4/Z2                                                                    24.300

    CRCI  =CTB  X R                                                                0.0
           PRE-IOC  CRCI =CRCI X Z6                                                0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                          0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                   0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0       17.307693     0.0
    USER FEE ESTABLISHED ON A PER FLIGHT BASIS.  FLIGHTS SUPPORT SCB AND LEO
    BASE FABRICATION.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.3.3.2.2 OPERATIONS - STS DERIVATIVE

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000			CDCER=	0.0
M=	1.000000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	63.000000			CICER=	15.190000
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	63.000000			BYEAR=	1979
DF=	1.000000	Z4=	63.000000	Z5=	0.0	Z6=	0.0

CALCULATED VALUES $ SUM TO 1.3.3.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	15.190
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	956.970
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	15.190
CIPS=CTB*Z4/Z2	15.949
CRCI =CTB X R	0.0
PRE-IOC CRCI =CRCI X Z6	0.0
POST-IOC CRCI =CRCI X (1.0-Z6)	0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR	0.0

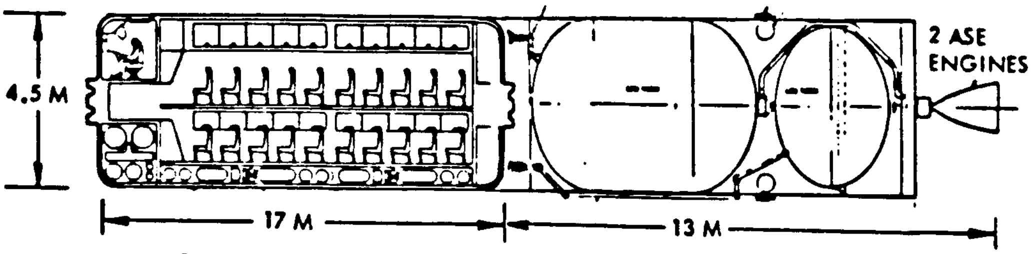
COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.0 12.982905 0.0
USER FEE ESTABLISHED ON A PER FLIGHT BASIS. FLIGHTSSUPPORT SCB AND
LEO BASE FABRICATION.

1.3.4 PERSONNEL ORBITAL TRANSFER VEHICLE (POTV)

This element includes POTV vehicles and operations required in support of satellite system assembly and operation. Included is the LEO-to-GEO and return of all personnel and priority cargo required throughout satellite construction and operational periods.

All POTV options evaluated utilize a single-state propulsive element that is fueled in LEO and refueled in GEO for the return flight. The mated configuration (POTV/PM) is illustrated in Figure 1.3-12 where the POTV (a propulsive chemical stage) is capable of transporting a 60-person module (PM) of 18,000 kg.



- 60 MAN CREW MODULE 18,000 KG
- SINGLE STAGE OTV (GEO REFUELING) 36,000 KG
- BOTH ELEMENTS CAPABLE OF GROWTH STS LAUNCH

Figure 1.3-12. POTV Configuration

The vehicle is costed in Section 1.3.4.1, and POTV operations are covered in Section 1.3.4.2.

1.3.4.1 POTV FLEET

The POTV fleet required to support the SPS program is included in this element. The POTV is a single-stage OTV of 36,000 kg for the transfer of a 60-person crew module to LEO with refueling at GEO for the return to LEO. Propellants are carried from LEO to GEO by the EOTV at considerable overall savings. The SPS HLLV carried construction materials, crew, expendables, and propellants to LEO.

The single-stage OTV configuration selected is a scaled version of those concepts presented in the BAC FSTSA NAS9-24323 contract and engineering analyses presented in Exhibits A/B of the Rockwell contract, NAS8-32475. DDT&E estimates considered fewer engines, a significant difference in mass, and the degree of development required for the engines. Engineering analyses of available vehicle estimates projected a POTV cost based on the design and complexity of the vehicle.

POTV cost estimates are presented in Table 1.3.4.1 for a total fleet of 45 vehicles with (1) 12 for personnel involved in satellite construction, (2) 3 for SPS operational activities, and (3) an attrition factor of 30 equivalent vehicles to keep the fleet fully operational.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.3.4.1 PUTV-FLEET

```
                INPUT PARAMETERS                                            INPUT COEFFICIENTS

   T=        1.000000    TF=       1.000000              CDCER=        409.500000
   M=        1.000000    O&M=      0.0                   CDEXP=          1.000000
  CF=        1.000000    Z1=       4.000000              CICER=         17.549988
 PHI=        0.950000    Z2=      60.000000              CIEXP=          1.000000
   R=        0.016666    Z3=      45.000000              BYEAR=              1979
  DF=        1.000000    Z4=      12.000000    Z5=           3.000000    Z6=          0.800000

    CALCULATED VALUES          SET          SUM TU  1.3.4
                                                                              $,MILLIONS
 CD=CDCER X (T X DF)XX(CDEXP) X CF
                                                                               409.500
 CLRM=CICER X (M)XX(CIEXP) X CF X TF
                                                                                17.550
 #RM =T / M
                                                                               1.000
 E   =1.0 + LOG(PHI) / LOG(2.0)
                                                                               0.926
 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))
                                                                                66.328

 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3          14.225

 CIPS=CTB*Z4/Z2
                                                                                 2.845
    CRCI  =CTB  X R                                                              0.237
          PRE-IOC  CRCI =CRCI X Z6                                               0.190
          POST-IOC CRCI =CRCI X (1.0-Z6)                                         0.047

    CO&M  =O&M OR CTB*Z5/Z2/ENYR
                                                                                 0.024
COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE   350.000000   15.000000    0.0
    45 PUTV VEHICLES WITH 12 CONSTRUCTION RELATED AND 3 O&M RELATED.  30 FOR
    RCI
```

1.3.4.2 POTV OPERATIONS

This element includes necessary vehicle operations (user charge per flight including payload integration) required to support SPS program and required personnel.

The primary operational cost of the POTV is the cost of fuel. A total of 1544 flights was costed on this basis with 1220 flights for satellite construction support, and 324 for operations and maintenance.

Table 1.3.4.2 presents the results of this analysis.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.3.4.2 POTV-OPERATIONS

INPUT PARAMETERS				INPUT COEFFICIENTS			
T=	1.000000	TF=	1.000000	CDCER=	0.0		
M=	1.000000	O&M=	0.0	CDEXP=	0.0		
CF=	1.000000	Z1=	40.000000	CICER=	0.040230		
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000		
R=	0.0	Z3=	1544.00000	BYEAR=	1979		
DF=	1.000000	Z4=	1220.00000	Z5=	324.000000	Z6=	0.0

```
CALCULATED VALUES      FLIGHTS          SUM TO  1.3.4                      $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                             0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                           0.040

#RM =T / M                                                                 1.000

E    =1.0 + LOG(PHI) / LOG(2.0)                                            1.000

CTFU=(CLRM / E)X((#RM X  Z1+.5)XX(E) -0.5XX(E))                               1.609

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3             0.040

CIPS=CTB*Z4/Z2                                                                0.818

   CRCI  =CTB  X R                                                            0.0
         PRE-IOC  CRCI =CRCI X Z6                                             0.0
         POST-IOC CRCI =CRCI X (1.0-Z6)                                       0.0

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                               0.007

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0        0.034385    0.0
```

1.3.5 PERSONNEL MODULE (PM)

This element includes PM units and operations required to support satellite system assembly and operation. Included in the earth-to-LEO-to-GEO and return is the transfer of all personnel and critical hardware items required throughout satellite construction and operational periods. The PM provides a crew habitat during the orbit-to-orbit transfer of personnel as well as during the trip from earth. An illustration of the PM was shown in Figure 1.3-12. It has a 60-man capacity and is approximately 17 m long by 4.5 m in diameter. The SPS HLLV is used for the earth-to-LEO and return transfer of personnel and the POTV propulsion unit handles roundtrip movement from LEO-GEO-LEO.

1.3.5.1 PM FLEET

Procurement of the PM as required to support the SPS program is covered in this element. The PM is operated by a pilot and co-pilot and contains the major systems of life support, communication, seating, and support facilities. A total of 5 PMs are needed to support the program, and three equivalent PMs are considered sufficient to provide spares and major overhaul components for each PM during the program. Two vehicles will be required for early program supporting elements such as the LEO base and SCB.

Engineering cost projections were based on Rockwell company-funded studies of 1976 where DDT&E, a pair of 68 passenger modules, and orbiter modification kits were costed from internal design specifications. PM fleet procurement costs are presented in Table 1.3.5.1.

```
                 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
   TABLE    1.3.5.1     PM FLEET

                   INPUT PARAMETERS                                        INPUT COEFFICIENTS

     T=           1.000000    TF=          1.000000          CDCER=          138.059998
     M=           1.000000   O&M=          0.0               CDEXP=            1.000000
    CF=           1.000000    Z1=          5.000000          CICER=           63.647995
   PHI=           0.920000    Z2=         60.000000          CIEXP=            1.000000
     R=           0.008333    Z3=         20.000000          BYEAR=                1979
    DF=           1.000000    Z4=          4.000000    Z5=         1.000000      Z6=          0.800000

   CALCULATED VALUES          SET          SUM TO   1.3.5
                                                                              $,MILLIONS
 CD=CDCER X (T X DF)XX(CDEXP) X CF
                                                                               138.060
 CLRM=CICER X (M)XX(CIEXP) X CF X TF
                                                                                63.648
 #RM =T / M
                                                                              1.000
 E   =1.0 + LOG(PHI) / LOG(2.0)
                                                                              0.880
 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))
                                                                               284.830

 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3           49.601

 CIPS=CTB*Z4/Z2
                                                                                 3.307
    CRC1  =CTB  X R
                                                                                 0.413
          PRE-IOC  CRC1 =CRC1 X Z6                                               0.331
          POST-IOC CRC1 =CRC1 X (1.0-Z6)                                         0.083

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                 0.028

 COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE   118.000000   54.399994    0.0
    INCLUDES TWO PM'S FOR STS (GROWTH) REQUIREMENTS TO BUILD THE SCB & LEO
    BASE.  THESE PM'S TO BE USED WITH 3 OTHERS FOR SRB, LEO BASE SPS CONSTR.
    AND O&M.
```

1.3.5.2 PM OPERATIONS

This element includes necessary operations on a user charge per flight basis required to support the SPS program.

A pilot and co-pilot command the personnel module with a crew of 60 persons from earth to GEO and return. The initial journey is from earth to LEO, a transfer of the PM to a propulsion (POTV) unit for a roundtrip mission to GEO, and the safe return of personnel to earth. The crew will monitor passenger off-loading/transfer to and from the LEO base, SCB, or satellite mobile maintenance base. Two man-days are required per trip which includes a rest period at GEO and a day off after the trip. An average of 1738 roundtrips are projected from earth to GEO and back. A total of 1346 is planned for construction, and 392 are for operations and maintenance.

Engineering estimates of PM operations are presented in Table 1.3.5.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.3.5.2 PM OPERATIONS

INPUT PARAMETERS					INPUT COEFFICIENTS		
T=	1.000000	TF=	1.000000		CDCER=	0.0	
M=	1.000000	O&M=	0.0		CDEXP=	0.0	
CF=	1.000000	Z1=	102.000000		CICER=	0.029250	
PHI=	1.000000	Z2=	60.000000		CIEXP=	1.000000	
R=	0.0	Z3=	1738.00000		BYEAR=	1979	
DF=	1.000000	Z4=	1346.00000	Z5=	392.000000	Z6=	0.0

CALCULATED VALUES FLIGHT SUM TO 1.3.5		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.029
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		2.983
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.029
CIPS=CTB*Z4/Z2		0.656
CRCI =CTB X R		0.0
PRE-IOC CRCI =CRCI X Z6		0.0
POST-IOC CRCI =CRCI X (1.0-Z6)		0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR		0.006

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.0 0.025000 0.0
1738 FLIGHTS OF PM. 1346 ASSOCIATED WITH CONSTRUCTION OF SATELLITES.
72 ASSOCIATED WITH CONSTRUCTION OF SCB AND LEO BASE. 392 FLIGHTS FOR
O&M SUPPORT.

1.3.6 INTRA-ORBITAL TRANSFER VEHICLE (IOTV)

This element includes IOTV vehicles and operations required to support satellite system assembly and operation. Included is the intra-orbit transfer of cargo between the HLLV, EOTV, construction facility, logistics support facility, and operational satellites.

1.3.6.1 IOTV FLEET

This element includes necessary vehicle fleet procurement required to support the SPS program. The IOTV has been synthesized in terms of application and concept only. IOTV elements considered here are powered by a chemical (LOX/LH_2) propulsion system. At least three distinct applications have been identified: (1) the need to transfer cargo from the HLLV to the EOTV in LEO and from the EOTV to the SPS construction base in GEO, (2) the need to move materials about the SPS construction base, and (3) the probable need to move men or materials between operational SPSs. Clearly, the POTV used for transfer of personnel from LEO to GEO and return is too large to satisfy all intra-orbit requirements. A "free-flyer" teleoperator concept would appear to be a logical solution to the problem. A propulsive element was synthesized to satisfy the cargo transfer application from HLLV-EOTV-SPS base in order to quantify potential on-orbit propellant requirements. Pertinent IOTV parameters are summarized in Table 1.3-9.

Table 1.3-9. IOTV Design Parameters

SUBSYSTEM	WEIGHT (kg)
ENGINE (1 ASE)	245
PROPELLANT TANKS	15
STRUCTURE AND LINES	15
DOCKING RING	100
ATTITUDE CONTROL	50
OTHER	100
SUBTOTAL	525
GROWTH (10%)	53
TOTAL INERT	578
PROPELLANT	300
TOTAL LOADED	878

A total of 417 IOTVs is needed to maintain intra-orbit cargo/operations flow during the program; 112 vehicles will be dedicated to the construction phase, and 27 vehicles are needed for satellite O&M. An attrition/spares fleet of equivalent vehicles was projected on the ratio of two units for each of the operational vehicles.

Cost estimates for the IOTV are engineering assessments based on POTV designs and similarities such as those of the common advanced space engine (ASE). Table 1.3.6.1 displays applicable cost data.

```
                ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
   TABLE   1.3.6.1    IOTV FLEET

                 INPUT PARAMETERS                              INPUT COEFFICIENTS

     T=          1.000000    TF=        1.000000        CDCER=        117.000000
     M=          1.000000   O&M=        0.0             CDEXP=          1.000000
    CF=          1.000000    Z1=        4.000000        CICER=          1.755000
   PHI=          0.950000    Z2=       60.000000        CIEXP=          1.000000
     R=          0.154445    Z3=      417.000000        BYEAR=              1979
    DF=          1.000000    Z4=      112.000000    Z5=        27.000000   Z6=        0.805755

   CALCULATED VALUES         SET         SUM TO  1.3.6                      $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                           117.000

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                           1.755

#RM =T / M                                                                  1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                              0.926

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                6.633


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3            1.212

CIPS=CTB*Z4/Z2                                                                2.262

   CRCI  =CTB  X R                                                            0.187
         PRE-IOC  CRCI =CRCI X Z6                                             0.151
         POST-IOC CRCI =CRCI X (1.0-Z6)                                       0.036

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                               0.018

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE   100.000000   1.500000   0.0
   IOTV LIFE TIME = 200 FLIGHTS.  RCI REQUIRES 2 IOTV'S FOR EACH FLIGHT
   ITEM INCLUDING A MINIMAL ALLOWANCE FOR O&M.
```

1.3.6.2 IOTV OPERATIONS

This element includes necessary IOTV operations and propellant costs required to support the SPS program. It includes the on-orbit operational cost of transferring cargo at LEO and GEO.

A total of 27,662 IOTV flights is planned for LEO and GEO construction and operations/maintenance requirements of the program; 22,323 flights are needed for construction, and 5339 flights for operations and maintenance. Equal-length missions are considered for the purposes of costing. Propellant requirements were averaged and calculated at 1979 dollars (Table 1.3-10). A 40% mark-up was added per flight for other operational and maintenance charges.

Table 1.3-10. Average Cost per IOTV Flight
(1979 Dollars)

Item	Amount $\times 10^6$ kg	\$/kg	\$/Flight
LO_2	0.000257	0.0819	21.00
LH_2	0.000043	3.826	165.00
		40% contingency	74.00
			260.00

IOTV operational costs are presented in Table 1.3.6.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.3.6.2 IOTV OPERATIONS

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	1.000000	TF=	1.000000			CDCER=	0.0		
M=	1.000000	U&M=	0.0			CDEXP=	0.0		
CF=	1.000000	Z1=	463.000000			CICER=	0.000260		
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000		
R=	0.0	Z3=	27662.0000			BYEAR=	1979		
DF=	1.000000	Z4=	22323.0000	Z5=	5339.00000			Z6=	0.0

CALCULATED VALUES FLIGHT SUM TO 1.3.6		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.000
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.120
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.000
CIPS=CTB*Z4/Z2		0.097
CRCI =CTB X R		0.0
PRE-IOC CRCI =CRCI X Z6		0.0
POST-IOC CRCI =CRCI X (1.0-Z6)		0.0
CU&M =U&M OR CTF*Z5/Z2/ENYR		0.001

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE 0.0 0.000222 0.0

1.3.7 GROUND SUPPORT FACILITIES

This element includes all land, buildings, roads, shops, etc., required to support the cargo handling, launching, recovery, refurbishment, and operations of the space transportation system.

1.3.7.1 LAUNCH FACILITIES

This element includes the design and construction of the actual launch facility and its associated equipment. Included are land, buildings, and equipment required to support the various crews. It also includes the required control centers and administrative facilities.

1.3.7.2 RECOVERY FACILITIES

This element covers the design, construction, and equipping of the actual recovery facilities.

1.3.7.3 FUEL FACILITIES

This element includes fuel production facilities, storage and handling facilities, transportation, and delivery and safety facilities for both the fuel and the oxidizer. Also included are the facilities for fuels used in the various orbital transfer facilities.

1.3.7.4 LOGISTICS SUPPORT

This element includes the land, buildings, and handling equipment for the receiving, inspection, and storage and packaging of all payloads to be launched except for fuels and oxidizers.

1.3.7.5 OPERATIONS

This element includes the planning, development, and conduct of operations at the ground support facilities. It includes both the direct and support personnel and the expendable maintenance supplies required for the ground support facilities operation and maintenance.

A cost estimate for ground support facilities is projected in Table 1.3.7, based on the Boeing final report (NAS9-14710), dated September 1977, Volume 4, Cost Estimates. These costs have been escalated to 1979 dollars. It was judged that there is little difference in the cost of facilities in this report as compared with those projected for the transportation and operations requirements of this study.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.3.7 GROUND SUPPORT FACILITIES

INPUT PARAMETERS					INPUT COEFFICIENTS		
T=	1.000000	TF=	1.000000		CDCER=	2012.39990	
M=	1.000000	O&M=	2.076749		CDEXP=	1.000000	
CF=	1.000000	Z1=	1.000000		CICER=	3738.15015	
PHI=	1.000000	Z2=	60.000000		CIEXP=	1.000000	
R=	0.001111	Z3=	3.000000		BYEAR=	1979	
DF=	1.000000	Z4=	1.000000	Z5=	0.0	Z6=	0.816661

CALCULATED VALUES FACILITY SUM TO 1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	2012.400
CLRM=CICER X (M)XX(CIEXP) X CF X TF	3738.150
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	3738.150
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	3738.148
CIPS=CTB*Z4/Z2	62.302
CRCI =CTB X R	4.153
PRE-IOC CRCI =CRCI X Z6	3.392
POST-IOC CRCI =CRCI X (1.0-Z6)	0.761
CO&M =O&M OR CTB*Z5/Z2/ENYR	2.077

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 1720.00000 3195.00000 1.775000
RCI BASED ON EQUIVALENT OF 2 FACILITY REPLACEMENTS OVER PROGRAM INCLUDING O&M
DURING CONSTRUCTION.O&M COSTS BASED ON EQUIVALENT OF ONE FACILITY OVER PROGRAM.

1.4 GROUND RECEIVING STATION

The ground receiving station (GRS) is equivalent to the ground segment and is made up of elements including the rectenna, power conversion, power distribution, grid interface, and data management systems, plus land and facilities. The GRS is designed to accept microwave energy from a satellite and to convert that energy into electrical power for the utility. A typical receiving station would be located at 34°N latitude.

The GRS site for the reference satellite requires approximately 35,000 acres. The rectenna site for the magnetron associated site will increase to about 42,000 acres, while the siting requirement for the solid-state system is expected to be less than 20,000 acres. Figure 1.4-1 shows a layout of the Rockwell reference SPS site. The inner ellipse of 10×13 km contains 580,500 rectenna panels and is about 25,000 acres, or 72% of the total GRS acreage. The rectenna dimensions for the magnetron, end-mounted, and sandwich solid-state concept are 10.95 km × 14.34 km, × 7.45 km × 9.76 km, and 4.87 km × 6.38 km, respectively. The area surrounding the inner ellipse is utilized for maintenance facilities, access roads, converter stations, and the two peripheral rows of towers which support the 40-kV dc and 500-kV ac cables. The outer perimeter of the area is fenced for security reasons. The towers which support the 500-kV ac cables are constructed of steel girders footed in concrete and are approximately 230 ft (70 m) high. The inner towers are each comprised for four tapered steel columns 60 ft (18.3 m) tall. Fifty-four of the larger towers and 401 of the smaller towers are required; the latter figure translating into 1604 tubular members because of the configuration.

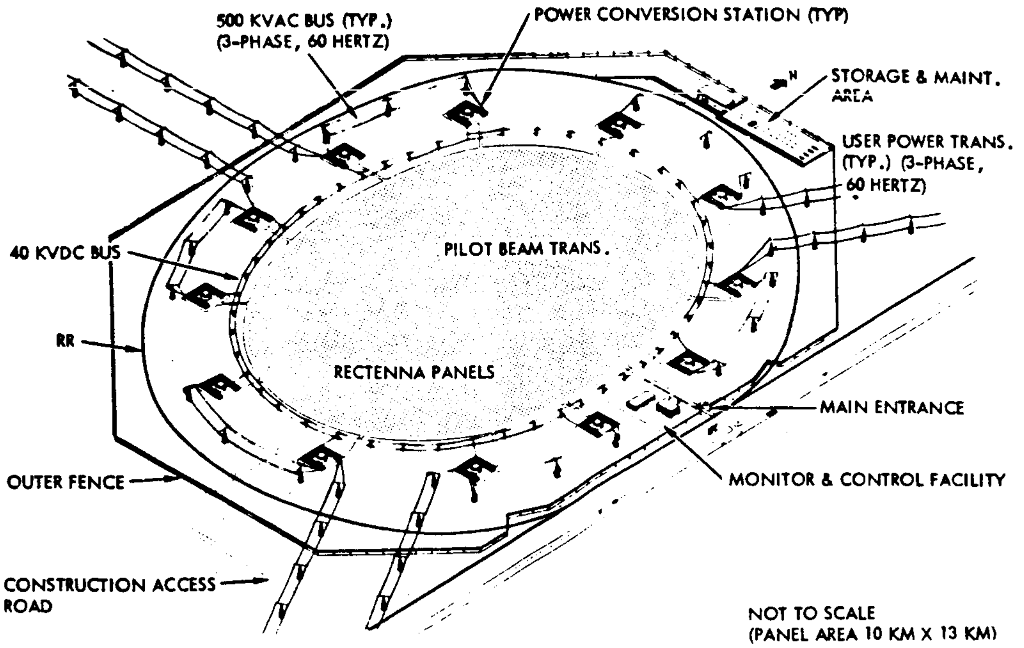


Figure 1.4-1. Operational Ground Receiving Facility (Rectenna)—Typical

Overall dimensions and area requirements for each of the five costed satellite configurations are summarized in Table 1.4-1. System point design characteristics for the klystron configuration are presented in Table 1.4-2.

Table 1.4-1. Ground Receiving Station Area Requirements

	Klystron (Rockwell Reference)	Magnetron	Solid State (Dual End Mount)	Solid State GaAs	Sandwich GaAlAs/ GaAs
Dimensions (km)			← per Antenna	→	
• Rectenna	10×13	10.95×14.3	7.45×9.76	4.87×6.38	5.47×7.16
• Perimeter	12×15	12.4 × 16.3	8.44×11.06	10.06×13.18	11.29×14.79
Land Area (km)					
• Rectenna	102.1	123.0	57.11	24.4	30.76
• Perimeter	141.4	158.7	73.31	104.13	131.15
Land Area (acres)					
• Rectenna	25,000	30,000	14,000	6,000	7,600
• Perimeter	35,000	39,000	18,000	26,000	32,000

Table 1.4-2. Rockwell Reference System Point Design Characteristics

GRS size (km), 35,000 acres	12×15
Rectenna ground area (km^2), 25,000 acres	102.1
Rectenna panel area (km^2)	79.53
Area per panel (9.33×14.69 m)	137.0
Number of panels	580,500
Number of diodes	330×10^6
Rectenna efficiency (%)	88
Voltage output per string (kV dc)	40+
Voltage output to utility (kV ac)	500
Power output (GW) at utilitie inter-tie	5.07*

*Based upon 6.15 GW incident radiation.

The ground based element of the SPS is comprised of the land, facilities, equipment, and hardware/software systems to receive the radiated microwave power beam and to provide the power at the required voltage and type of current for entry into the national power grid. It also includes the equipment, facilities, and hardware/software necessary to provide operational control over the satellite; and a reliable means of monitoring and controlling ground based systems and equipment.

Major objectives of the SPS ground system design are: (1) to provide low maintenance subsystems and equipment capable of handling the designed power

levels; (2) to assure that the overall station will provide dependable service for at least 30 years; (3) to minimize the size of operational crews and costs; and (4) to economically optimize system performance.

There are nine major activities involved in the overall GRS construction process. After the survey and clearing, utilities and supporting facilities are installed while the site is leveled and graded. Trenching and concrete pouring precede the installation of rectenna panels, after which electrical hook-up, converter stations, and monitoring facilities are installed. The 40-kV dc and 500-kV ac buses are then interconnected and procedures take place for system checkout. Cost effective utilization of equipment and personnel was identified after the development and integration of detail phasing schedules on each of the first four ground stations. Contacts with A&E, equipment manufacturers, concrete, and construction firms provided additional information on the duration and sequence of operations based on their experience with programs of this type. Figure 1.4-2 is an integrated summary schedule of major events in constructing the ground receiving station where emphasis is placed on the utilization of construction equipments and their transfer from site to site as required to maintain the build rate of two stations per year. It was concluded that the equipment from Site 1 would be available for use on Site 3. This information on equipment/manpower utilization, site sequencing, and equipment lifetimes is used in this analysis to establish total resource requirements for the program.

The ground receiving station was divided into several main elements for the purpose of associating cost and programmatic definitions. These elements include (1) site and facilities, (2) rectenna support structure, (3) power collection, (4) control, (5) grid interface, and (6) operations. SPS design definitions and specification requirements were analyzed to provide realistic cost estimates and resource definitions for each element as explained in the following sections.

Internal Rockwell resources, cost estimating relationships, and other cost analyses were supplemented by (1) direct contact with business, industry, and institutional organizations, and (2) a literature search of various publications to obtain realistic cost estimates and operational definitions directly applicable to the unique requirements of the GRS. A list of principal organizations and literature sources are presented in Table 1.4-3.

A summary of costs associated with the Rockwell reference GRS is presented in Table 1.4-4. Detail supporting these costs is presented on subsequent pages of this section.

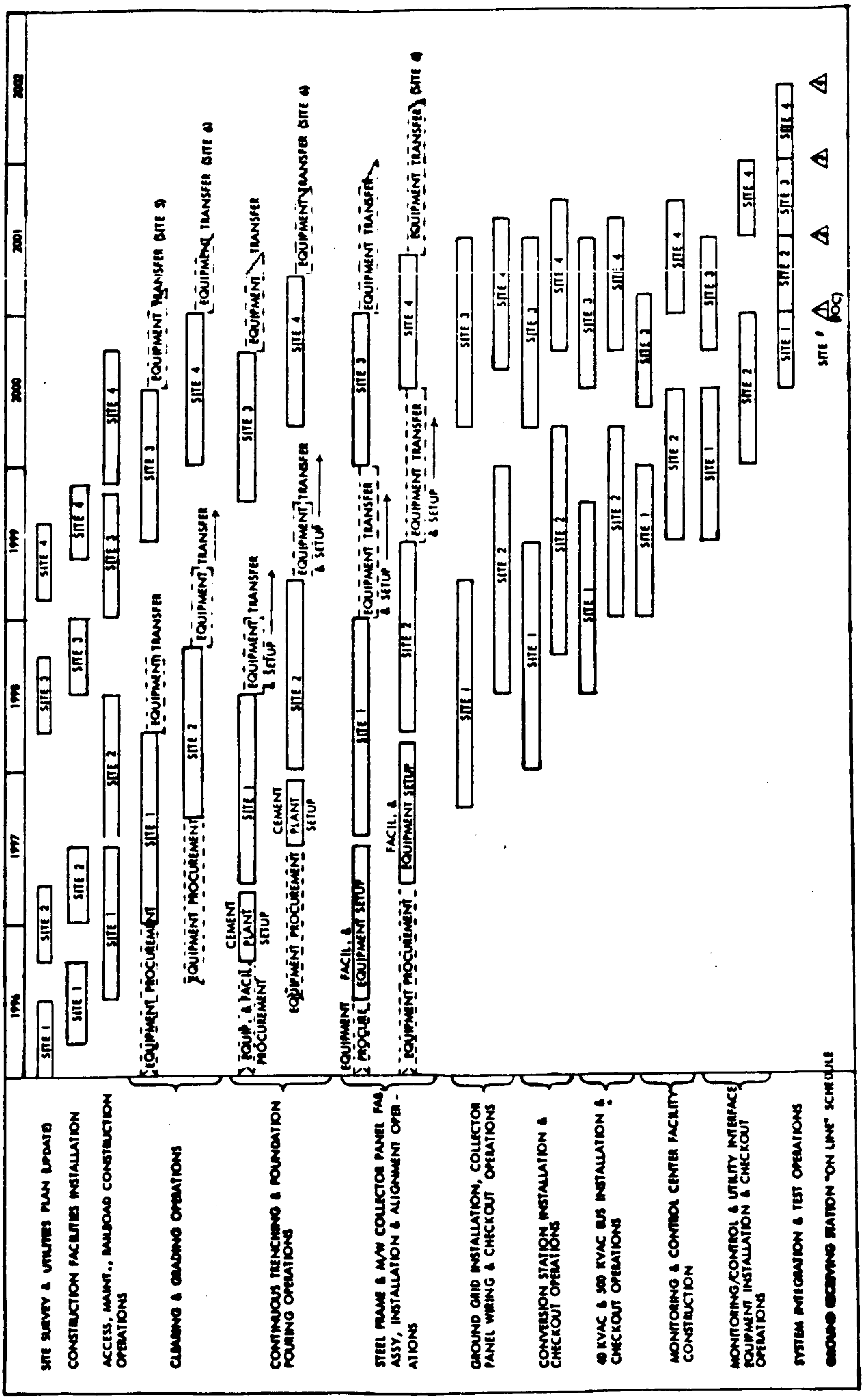


Figure 1.4-2. Rectenna Construction Sequence Summary Schedule

Table 1.4-3. Organizations and Literature Sources Supporting GRS Definition

ORGANIZATION	PURPOSE
• AMERICAN BRIDGE - A DIVISION OF U.S. STEEL	TO DEVELOP STEEL REQUIREMENTS, COSTS AND OPERATIONS DEFINITION FOR PROCUREMENT AND INSTALLATION OF RECTENNA SUPPORT STRUCTURE
• RIVERSIDE CEMENT - A DIVISION OF AMERICAN CEMENT CORPORATION; AND C. S. JOHNSON, CO.	PROVIDE CONSULTATION ON CEMENT/CONCRETE SPECIFICATIONS, OPERATIONAL METHODS, PROCESSING/HANDLING EQUIPMENT, AND CONCRETE PLANT
• TOWNSEND & BOTTUM, INC., CONSTRUCTION MANAGER, TEN MW SOLAR PLANT - BARSTOW, CA.	DISCUSS SITE PREPARATION, CONSTRUCTION OPERATIONS/SEQUENCING, PLUS ACTIVATION REQUIREMENTS
• SOUTHERN CALIFORNIA EDISON	TO DISCUSS DC/AC POWER DISTRIBUTION AND CONVERSION REQUIREMENTS, AND OBTAIN COST ESTIMATES ON INSTALLATION OF LINES/TOWERS
• MODERN ALLOYS, INC.; AND MILLER FORMLESS CO.	TO DISCUSS USE AND APPLICATION OF EQUIPMENT/CREW FOR CONTINUOUS CONCRETE POUR OF RECTENNA SUPPORT STRUCTURE FOOTINGS
• CATERPILLAR; INTERNATIONAL HARVESTER; AND JETCO, INC.	OBTAIN PRICES ON EARTH MOVING, GRADING AND TRENCHING EQUIPMENT
LITERATURE SOURCES	
• THE RICHARDSON RAPID SYSTEM 1978-1979 EDITION	CONSTRUCTION LABOR AND OPERATIONS PRICES
• ENGINEERING NEWS RECORD - 1977 A WEEKLY McGRAW-HILL PUBLICATION	CEMENT, AGGREGATE AND LABOR PRICES
• NATIONAL CONSTRUCTION ESTIMATING GUIDE (NCE)	CONSTRUCTION OPERATIONS

Table 1.4-4. GRS Cost Summary (1979 Dollars in Millions)

WBS No.	Rockwell Reference Configuration	DDT&E	TFU	ICI	RCI/O&M (SAT/YR)	
					Pre-IOC	Post-IOC
1.4.1	Site and facilities	1.2	228.4	221.0	-	0.3
1.4.2	Rectenna support structure	2.3	2164.2	2138.9	1.7	-
1.4.3	Power collection	3.5	1583.3	1583.2	-	-
1.4.4	Control	11.7	87.7	87.8	-	-
1.4.5	Grid interface	116.7	186.2	186.2	-	-
1.4.6	Operations	-	-	-	-	31.6
	Total	135.4	4249.8	4217.1	1.7	31.9

1.4.1 SITE AND FACILITIES

The ground receiving station is located on a site of 35,000 acres where over 25,000 acres of a central ellipse, or 72% of the total acreage, is used for rectenna panels. The area surrounding the inner ellipse is allocated for maintenance/control facilities, access roads, converter stations, and the rows of towers that support the 40 kW dc and 500 kV ac cables. The GRS perimeter is fenced for security reasons.

The sequence of construction operations begins with site identification, environmental impact studies, zoning/permits, surveys, utility/road installation, and supporting facilities. After reference coordinates are established, the site is cleared, leveled, and followed with precise grading for panel foundations, fabrication facilities, installation, and GRS site completion. This includes concrete mixing plants, rectenna panel fabrication factories, crew accommodations, warehousing, and support facilities as shown in Figure 1.4-3. The GRS DDT&E effort will be a valuable asset to all GRS sites by providing designs, analyses, and procurement specifications for commonly used buildings and facilities.

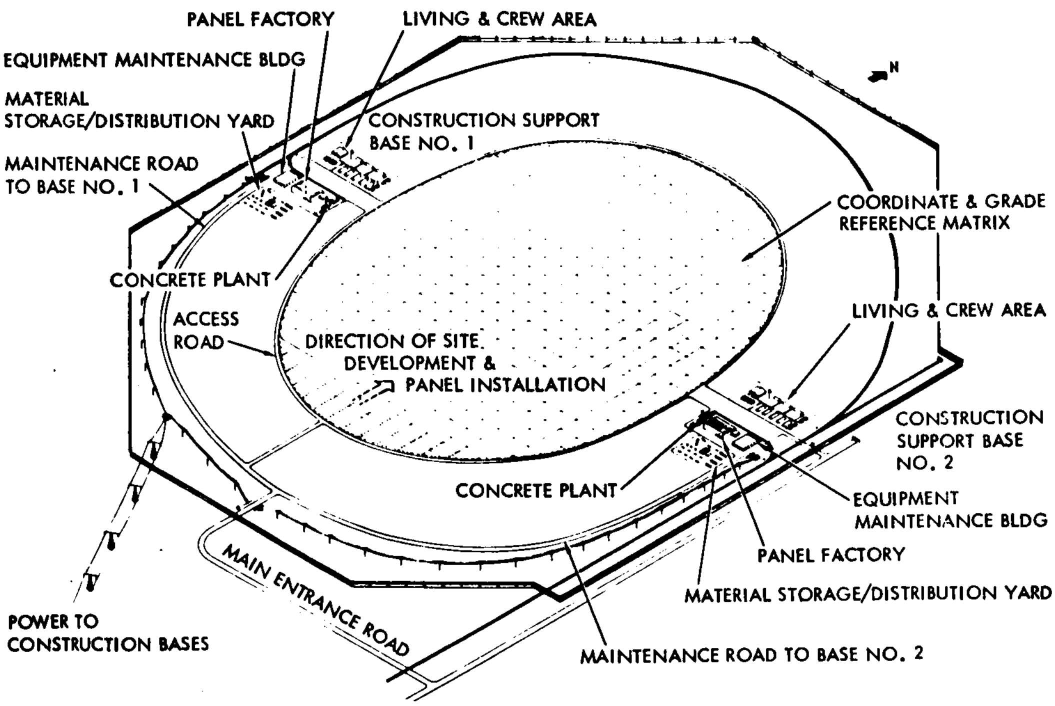


Figure 1.4-3. Support Facilities

Clearing and leveling operations will occur at a number of locations within the panel farm perimeter. These operations consist of tree removal (if required), grading, and leveling the terrain to acceptable slope angles, and removing excess dirt. Sixteen areas of the ellipse would be cleared and leveled simultaneously. Site topographics were assumed at a 1:30 maximum average grade of non-forested land. These ground rules lead to an appropriate identification of equipment.

Bulldozers will make the initial cut, scrapers will grade to more precise requirements, and an estimate was made of one crew of 13 men to grade eight acres per day. The crew and equipment required to prepare a 35,000-acre site were established based on a single shift that would level 130 acres per day to meet a nine-month schedule (reference contacts with heavy equipment distributors). A control center is envisioned for traffic monitoring and synchronized operations as the grading system moves through its operational sequencing. Contingencies for weather, shift changes, rest periods, etc., have been considered through the planning of a 20-hour day.

Costs developed for GRS site and facilities are divided into the elements of land, site preparation, roads and fence, utilities, buildings and facilities, maintenance equipment, lightning protection, and DDT&E. Basic design parameters used in this costing are presented in Table 1.4-5.

Table 1.4-5. Site and Facilities Requirements

Item	Unit Parameter
Land/fencing	35,000 acres
Grading/leveling	Heavy equipment/crew size
Preparation	Survey, EIR, permits, A&E planning
Utilities	Water, electricity, gas, sewage
Roads/rails	Roads—35 miles, rails—45 miles
Facilities	Conversion station, monitor and control, maintenance/storage
Drainage	6-in. gravel for combination access-way and drainage between panel rows
Lightning protection	TBD

DDT&E, investment, and operations costs (1979 dollars) established for each element of site and facilities are presented in the following tables:

Category	Table
Land and Preparation	Land—1.4.1.1.1 Preparation—1.4.1.1.2
Roads and Fences	Rails and Roads—1.4.1.2.1 Fencing—1.4.1.2.2
Utilities	1.4.1.3
Buildings and Facilities	Storage/Maintenance—1.4.1.4.1 Converter Station—1.4.1.4.2
Maintenance Equipment	1.4.1.5
Lightning Protection System	1.4.1.6
Site and Facilities DDT&E	1.4.1.7

```
              ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
    TABLE   1.4.1.1.1   LAND

                 INPUT PARAMETERS                                      INPUT  COEFFICIENTS

     T=       35000.0000      TF=        1.000000        CDCER=          0.0
     M=       35000.0000     O&M=        0.0             CDEXP=          0.0
    CF=           1.000000    Z1=        1.000000        CICER=          0.001170
   PHI=           1.000000    Z2=       60.000000        CIEXP=          1.000000
     R=           0.0         Z3=       60.000000        BYEAR=             1979
    DF=           1.000000    Z4=       60.000000   Z5=          0.0        Z6=          1.000000

    CALCULATED VALUES       ACRES        SUM TO  1.4.1.1                      $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                             0.0

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                          40.950

 #RM =T / M                                                                 1.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                             1.000

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                               40.950


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3          40.950

 CIPS=CTB*Z4/Z2                                                               40.950

     CRCI  =CTB  X R                                                           0.0
           PRE-IOC  CRCI =CRCI X Z6                                            0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                      0.0

     CO&M  =O&M OR CTB*Z5/Z2/ENYR                                              0.0

 COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0        0.001000    0.0
     RECTENNA 10 KM X 13 KM WITH BUFFER ZONE.
```

```
                 RUCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE    1.4.1.1.2  LAND PREPARATION

              INPUT PARAMETERS                                          INPUT COEFFICIENTS

  T=       35000.0000      TF=         1.000000          CDCER=          0.0
  M=       35000.0000     O&M=         0.0               CDEXP=          0.0
 CF=           1.000000    Z1=         1.000000          CICER=          0.002348
PHI=           0.980000    Z2=        60.000000          CIEXP=          1.000000
  R=           0.0         Z3=        60.000000          BYEAR=              1979
 DF=           1.000000    Z4=        60.000000    Z5=          0.0         Z6=        1.000000

 CALCULATED VALUES         ACRES           SUM TO  1.4.1.1                       $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                   0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                82.187

#RM =T / M                                                                       1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                   0.971

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                     82.298

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               75.019

CIPS=CTB*Z4/Z2                                                                     75.019

   CRC1  =CTB  X R                                                                  0.0
         PRE-IOC  CRC1 =CRC1 X Z6                                                   0.0
         POST-IOC CRC1 =CRC1 X (1.0-Z6)                                             0.0

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                     0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0         0.002007    0.0
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.4.1.2.1 RAILS AND ROADS

```
                INPUT PARAMETERS                                    INPUT COEFFICIENTS

   T=         1.000000    TF=        1.000000          CDCER=         0.0
   M=         1.000000   U&M=        0.0               CDEXP=         0.0
  CF=         1.000000    Z1=        1.000000          CICER=        86.240707
 PHI=         1.000000    Z2=       60.000000          CIEXP=         1.000000
   R=         0.0         Z3=       60.000000          BYEAR=            1979
  DF=         1.000000    Z4=       60.000000    Z5=         0.0          Z6=          1.000000

   CALCULATED VALUES          SET          SUM TO  1.4.1.2                      $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                  0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               86.241

#RM =T / M                                                                      1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                  1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                    86.241


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               86.241

CIPS=CTB*Z4/Z2                                                                    86.241

    CRCI  =CTB  X R                                                                0.0
          PRE-IOC  CRCI =CRCI X Z6                                                 0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                           0.0

    CO&M  =U&M OR CTB*Z5/Z2/ENYR                                                   0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND U&M WERE      0.0        73.710007    0.0
    ACCESS AND PERIMETER ROADS.  GRAVEL ROADS AT RECTENNA ROWS.
    PERIMETER SPUR AND ACCESS RAILROAD.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.4.1.2.2 FENCING

```
                    INPUT PARAMETERS                                          INPUT COEFFICIENTS

      T=     42671.0000      TF=        1.000000          CDCER=          0.0
      M=     42671.0000     O&M=        0.0               CDEXP=          0.0
     CF=        1.000000     Z1=        1.000000          CICER=          0.000013
    PHI=        0.980000     Z2=       60.000000          CIEXP=          1.000000
      R=        0.0          Z3=       60.000000          BYEAR=             1979
     DF=        1.000000     Z4=       60.000000    Z5=         0.0          Z6=          1.000000

   CALCULATED VALUES          M           SUM TO  1.4.1.2                          $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                    0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                  0.549

#RM =T / M                                                                        1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                    0.971

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                       0.550

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                  0.501

CIPS=CTB*Z4/Z2                                                                       0.501

    CRCI  =CTB  X R                                                                  0.0
          PRE-IOC  CRCI =CRCI X Z6                                                   0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                             0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                     0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0        0.000011     0.0
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.4.1.3 UTILITIES

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000			CDCER=	0.0
M=	1.000000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	1.000000			CICER=	0.234000
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	60.000000			BYEAR=	1979
DF=	1.000000	Z4=	60.000000	Z5=	0.0	Z6=	1.000000

CALCULATED VALUES SET SUM TO 1.4.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.234
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	0.234
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	0.234
CIPS=CTB*Z4/Z2	0.234
CRCI =CTB X R	0.0
PRE-IOC CRCI =CRCI X Z6	0.0
POST-IOC CRCI =CRCI X (1.0-Z6)	0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.0 0.200000 0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.4.1.4.1 STORAGE,MAINTENANCE FACILITIES

```
                 INPUT PARAMETERS                                     INPUT COEFFICIENTS

   T=      1.000000    TF=     1.000000            CDCER=      0.0
   M=      1.000000   U&M=     0.0                 CDEXP=      0.0
  CF=      1.000000    Z1=     1.000000            CICER=      1.521000
 PHI=      1.000000    Z2=    60.000000            CIEXP=      1.000000
   R=      0.0         Z3=    60.000000            BYEAR=         1979
  DF=      1.000000    Z4=    60.000000     Z5=        0.0       Z6=         1.000000

  CALCULATED VALUES         $        SUM TO  1.4.1.4                      $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                          0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                        1.521

#RM =T / M                                                              1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                          1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                             1.521


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))      ) / Z3            1.521

CIPS=CTB*Z4/Z2                                                             1.521

   CRCI  =CTB   X R                                                        0.0
          PRE-IOC  CRCI =CRCI X Z6                                         0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                   0.0

   CO&M  =U&M OR CTB*Z5/Z2/ENYR                                            0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE    0.0     1.300000   0.0
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.4.1.4.2 CONV. STA. & MONITOR/CONTROL FAC.

INPUT PARAMETERS					INPUT COEFFICIENTS		
T=	21290.0000	TF=	1.000000		CDCER=	0.0	
M=	21290.0000	O&M=	0.0		CDEXP=	0.0	
CF=	1.000000	Z1=	1.000000		CICER=	0.000559	
PHI=	1.000000	Z2=	60.000000		CIEXP=	1.000000	
R=	0.0	Z3=	60.000000		BYEAR=	1979	
DF=	1.000000	Z4=	60.000000	Z5=	0.0	Z6=	1.000000

CALCULATED VALUES SQ M SUM TO 1.4.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	11.907
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	11.907
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	11.907
CIPS=CTB*Z4/Z2	11.907
CRCI =CTB X R	0.0
PRE-IOC CRCI =CRCI X Z6	0.0
POST-IOC CRCI =CRCI X (1.0-Z6)	0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS
1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.0 0.000478 0.0

```
                 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
    TABLE    1.4.1.5     MAINTENANCE EQPT. FOR SITE & FACILITIES

                  INPUT PARAMETERS                                  INPUT COEFFICIENTS

      T=          1.000000    TF=        1.000000         CDCER=          0.0
      M=          1.000000   O&M=        0.093600         CDEXP=          0.0
     CF=          1.000000    Z1=        1.000000         CICER=          4.680000
    PHI=          1.000000    Z2=       60.000000         CIEXP=          1.000000
      R=          0.050000    Z3=      150.000000         BYEAR=             1979
     DF=          1.000000    Z4=       60.000000    Z5=         0.0          Z6=          0.0

     CALCULATED VALUES         SET          SUM TO  1.4.1                          $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 0.0

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               4.680

  #RM =T / M                                                                    1.000

  E   =1.0 + LOG(PHI) / LOG(2.0)                                                1.000

  CTFU=(CLRM / E)X((#RM X  Z1+.5)XX(E) -0.5XX(E))                                   4.680


  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               4.680

  CIPS=CTB*Z4/Z2                                                                    4.680

     CRCI   =CTB  X R                                                               0.234
            PRE-IOC  CRCI =CRCI X Z6                                                0.0
            POST-IOC CRCI =CRCI X (1.0-Z6)                                          0.234

     CO&M   =O&M OR CTB*Z5/Z2/ENYR                                                  0.094

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0        4.000000    0.080000
     MAINT. EQUIP., TOOLS, STE, FOR MAINTENANCE OF RECTENNA.
```

```
                 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
      TABLE    1.4.1.6     LIGHTNING PROTECTION

                    INPUT PARAMETERS                                   INPUT COEFFICIENTS

      T=            0.0          TF=         1.000000        CDCER=          0.0
      M=            0.0         O&M=         0.0             CDEXP=          0.0
     CF=            0.0          Z1=         1.000000        CICER=          0.0
    PHI=            1.000000     Z2=        60.000000        CIEXP=          0.0
      R=            0.0          Z3=        60.000000        BYEAR=              1979
     DF=            1.000000     Z4=        60.000000    Z5=         0.0     Z6=        1.000000

      CALCULATED VALUES          $           SUM TO  1.4.1                      $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 0.0

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               0.0

  #RM =T / M                                                                    0.0

  E   =1.0 + LOG(PHI) / LOG(2.0)                                                0.0

  CTFU=(CLRM / E)X((#RM X  Z1+.5)XX(E) -0.5XX(E))                                   0.0


  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3              0.0

  CIPS=CTB*Z4/Z2                                                                    0.0

      CRCI  =CTB  X R                                                               0.0
             PRE-IOC  CRCI =CRCI X Z6                                               0.0
             POST-IOC CRCI =CRCI X (1.0-Z6)                                         0.0

      CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                  0.0

  COMMENTS
      1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0        0.0        0.0
```

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.4.1.7     SITE & FACILITIES DDT&E

                INPUT PARAMETERS                                   INPUT COEFFICIENTS

     T=          1.000000    TF=       1.000000          CDCER=        1.170000
     M=          1.000000    O&M=      0.0               CDEXP=        1.000000
    CF=          1.000000    Z1=       1.000000          CICER=        0.0
   PHI=          1.000000    Z2=      60.000000          CIEXP=        0.0
     R=          0.0         Z3=      60.000000          BYEAR=            1979
    DF=          1.000000    Z4=      60.000000    Z5=         0.0       Z6=          1.000000

     CALCULATED VALUES          $          SUM TO  1.4.1                    $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                            1.170

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                          0.0

 #RM =T / M                                                                 1.000

 E    =1.0 + LOG(PHI) / LOG(2.0)                                            1.000

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                               0.0


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3           0.0

 CIPS=CTB*Z4/Z2                                                               0.0

    CRCI   =CTB  X R                                                          0.0
         PRE-IOC  CRCI =CRCI X Z6                                             0.0
         POST-IOC CRCI =CRCI X (1.0-Z6)                                       0.0

    CO&M   =O&M OR CTB*Z5/Z2/ENYR                                             0.0

 COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      1.000000    0.0       0.0
```

1.4.2 RECTENNA SUPPORT STRUCTURE

The rectenna farm area of 102.1 $(km)^2$ is covered by 580,500 panels that have a total mW intercept area of 79.53 $(km)^2$. Each panel (9.33 m × 14.69 m) is tilted at an angle of 40° to the horizontal and is mounted on two continuous ribbons of concrete as shown in Figure 1.4-4. Procurement, fabrication, assembly and installation of the steel rectenna support structure, and the placement of a supporting foundation are costed in this section and represent results of consultation and discussions with experienced individuals from industrial and construction organizations.

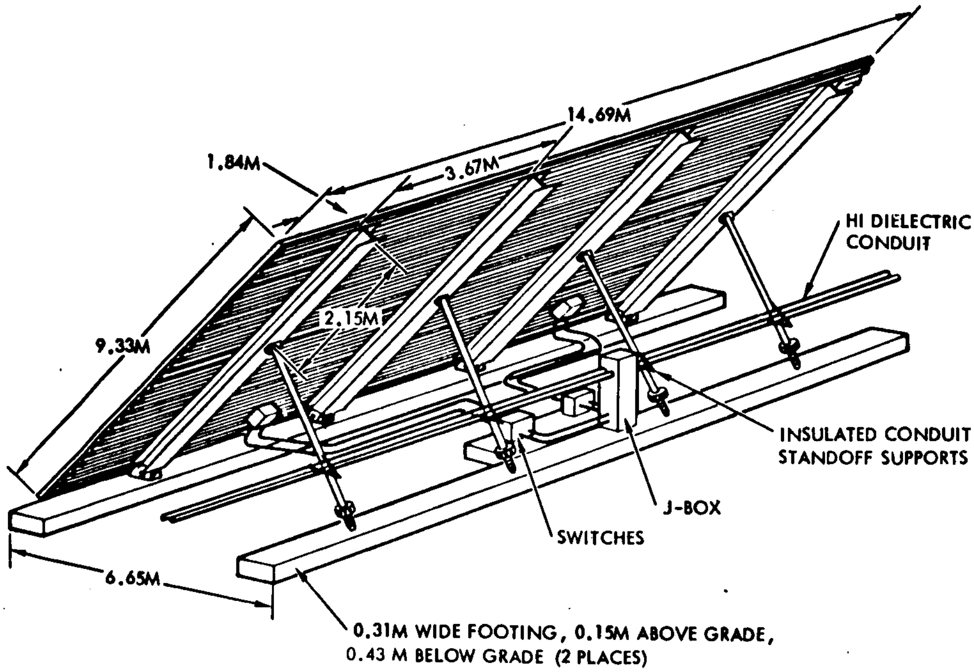


Figure 1.4-4. Panel Installation

1.4.2.1 PANEL STRUCTURE

The rectenna panel structure is comprised of four standard size eight-inch (wide flange) I beams, supporting tube braces, and 18 hat-shaped sections for the mounting of power collection electronic elements and the maintenance of panel rigidity. Tube braces, steel cast fittings and attachment hardware are used to support the panel on continuous footing as shown in Figure 1.4-5.

A detail analysis of the support structure was completed to identify the amount of material needed; necessary fabrication, operations, assembly, and installation requirements; and to estimate manpower and equipments needed to produce the average daily production requirement of 2150 panels over the nine-month period. The cost of processed materials for a rectenna panel is shown in 1.4-6.

The rectenna panel hat section serves as a mounting surface for the laminated-copper-clad mylar array elements. (See Section 1.4.3, Power Collection). Adhesives will be used to mount the elements to the structure to provide continuous support and added strength with a minimum of localized panel deflection.

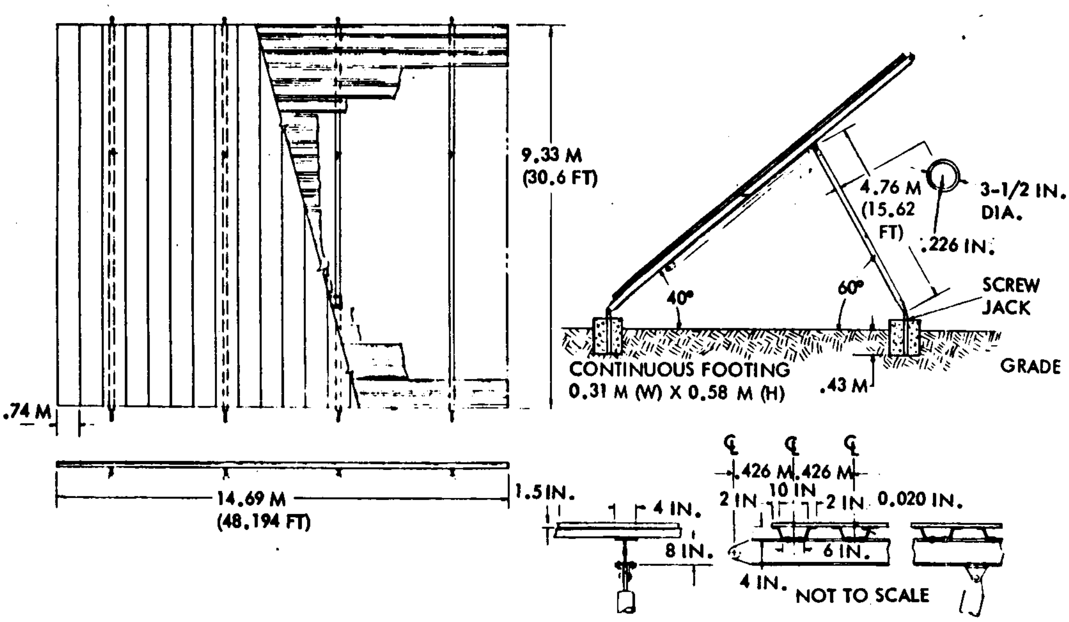


Figure 1.4-5. Rectenna Array Support Structure

ITEM/DESCRIPTION	DIMENSIONAL DATA	NUMBER REQ'D	TOTAL WEIGHT	PREFAB & DELIVERED COST/PANEL *
HAT SECTIONS	14.69M LONG; 6"; 4"; 2"; .020"	18	1288# 584.25 kg	$ 723.34
I-BEAMS	9.33M LONG; 3.94"; 0.170; 7.90"; 0.204	4	1589# 720.75 kg	$ 594.92
TUBE BRACES	4.76M LONG; 0.226"; 3.50"	4	1104# 500.75 kg	$ 905.30
HARDWARE FITTINGS & WELDING ROD		4 SETS		
RETURNED SCRAP ALLOWANCE			-307# -139 kg	$ -35.92
COST PER PANEL			3674# 1666.75 kg	$2187.64

*1979 dollars

Figure 1.4-6. Rectenna Panel Support Structure

The basic hat section is formed at the rectenna site from 0.020-inch galvanized steel sheet stock by processing through a set of forming rollers in a continuous manner. The forming machine (Yoder mill) accommodates widths of rolled mill stock sufficient to produce the finished hat sections ready for assembly to the I beams.

Four standard wide-flange 8-inch galvanized steel I-beams are required in lengths of 9.33 m for each rectenna panel. This material will be delivered to the site in precut lengths for hole punching and the addition of brackets/machined castings for support braces and panel mounting.

Four 3.5-inch-diameter tube braces of galvanized steel are cut to a length of 4.76 m and preassembled to the fittings/hardware. Anchors, brackets, clips, hangers, etc., are fabricated or cast of carbon steel material and galvanized prior to machining at the site. All these items are scheduled to combine with the hat sections and I-beams at a centralized facility for assembly. A concept for such a facility is shown in Figure 1.4-7. The factory has multiple assembly lines where each line has a materials feed section, steel assembly facilities, electronics assembly and checkout section. It was assumed that one line using automated procedures could assemble and checkout a panel in 40 minutes. On this basis, seventy-two assembly lines operating 20 hours per day, seven days a week are required to produce 580,500 panels in the allocated 270 days.

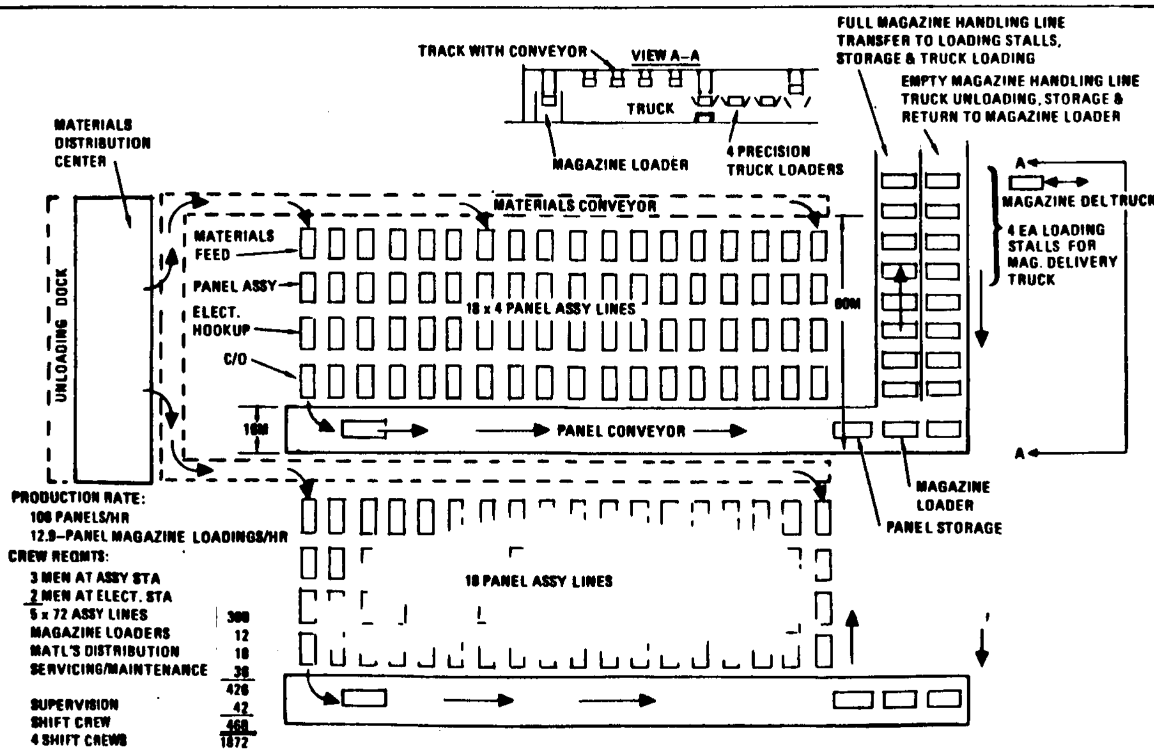


Figure 1.4-7. Central Panel Factory

After the panels have been checked, they are placed on an overhead conveying system and transported to loading stalls, where they are assembled into 9-panel magazines and loaded on specially designed trucks for delivery to the point of installation. Automated assembly and installation costs were estimated at $1231 per panel.

Specialized equipment is required to deliver the panels from the factory to the installation point and to install them because of their large dimensions. After consultation with industrial sources on large equipment handling, a concept for a specialized machine was developed (Figure 1.4-8). The front and rear wheel pairs are each steerable as a unit and have provisions for height adjustment. The panels are transferred in magazines and lifted by means of fixtures mounted in vertical rails. They can be translated laterally and longitudinally for final positioning before attachment to the footings.

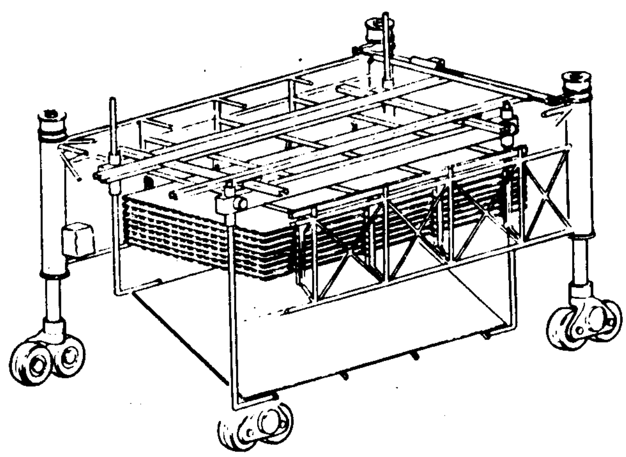


Figure 1.4-8. Panel Loading Sequence

1.4.2.2 TRENCHING AND CONCRETE FOOTINGS

A cost trade-off was made to consider eight individual footings versus continuous footings. A maximum wind force of 90 m/hr was assumed at rectenna panels mounted on the footings. It was determined that the amount of concrete required for either approach was essentially the same, but that the continuous footing concept was easier to install and required fewer operations and less capital equipment.

Each panel is secured to the footings at eight locations by fittings (brackets) which are imbedded in concrete during the pouring operation. Mounting attachments which provide for longitudinal and lateral adjustment are secured to the fittings. Screw jacks on each of the rear attach points provide for panel adjustment and alignment (reference Figure 1.4-5).

Table 1.4-6 summarizes costs of crew and equipment requirements for the placement of footings based on a nine-month schedule to prepare 1088 panel rows per rectenna.

Table 1.4-6. Concrete Footing Equipment/Crew

ITEM/DESCRIPTION	SITE CONSTRUCTION QUANTITY	1979 UNIT PRICES	TOTAL COST (1979 DOLLARS)
TRENCHERS - JW-2	38	$81,900	$3,112,200
DUMP TRUCKS - CAT 773	26	$409,500	$10,647,000
CONCRETE DELIVERY VEHICLES - 10 C.Y.	190	$58,500	$11,115,000
CONCRETE FORMING MACHINES	10	$70,200	$702,000
CONCRETE CENTRAL MIX PAVING PLANTS	2	$292,500	$585,000
TOTAL COST			$26,161,200
TRENCHING & CONCRETE CREW PERSONNEL	1480		

The footings of continuous concrete are 0.43 meters deep, 0.31 meters wide, and project 0.15 meters above ground level. Two footings are excavated simultaneously by trenchers which feed the removed dirt into a truck. Approximately 17×10^6 meters of trenches must be excavated. To accomplish this, 38 trenchers are required, each trencher excavating 90 meters per hour. A well developed plan is contemplated by the placement of concrete footings in order to maximize labor requirements, avoid congestion, and improve operational sequences that deal with this highly repetitive activity on site after site.

Each rectenna panel will be mounted and aligned on 6.8 cu yds of concrete placed by concrete formers such as those commonly used in freeway divider construction. The formers extrude a shaped ribbon at rates of 6 meters per minute. Reinforcing steel and panel attach fittings are inserted as the concrete is vibrated during the extrusion process. Concrete footing requirements for rectenna panels are shown in Table 1.4-7.

1.4.2.3 COST ESTIMATES

DDT&E, investment, construction/installation, and operations costs of rectenna structures (less electronic elements) and the concrete footings needed to support these structures are identified in the following tables:

Rectenna Panel Fab. & Installation

Table 1.4.2.1.1 Hat Sections

Table 1.4.2.1.2 Wide Flanges

Table 1.4.2.1.3 Tube Braces & Hardware

Table 1.4-7. Concrete Footing Requirements per Panel

ITEM/DESCRIPTION	1979 $ (MILL PRICE DELIVERED)	INGREDIENTS FOR 6.8 CU.YDS.	MATERIAL COST DELIVERED (1979 Dollars)
CEMENT (5 SACK) (94# SACK)	$49.10/TON	3196#	$78.53
SAND	$5.28/TON	9520#	$25.12
ROCK 1"-1½"	$5.14/TON	12444#	$31.96
WATER	-	2040#	0
REINFORCING STEEL - #4	$0.12/LB	64#	$7.53
TOTAL/PANEL		27264#	
DELIVERED 1977 MILL PRICES PER ENGINEERING NEWS RECORD (ENR) - McGRAW HILL, (AN INDUSTRY PUBLICATION) HAVE BEEN ESCALATED TO 1979 DOLLARS			

Table 1.4.2.1.4 Assembly & Installation

Trenching and Concrete Installation

Table 1.4.2.2.1 Footing Concrete & Rebar

Table 1.4.2.2.2 Machinery & Equipment

Table 1.4.2.2.3 Construction Operations

Rectenna Panel DDT&E

Table 1.4.2.3 Support Structure DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.4.2.1.1 HAT SECTIONS

```
                    INPUT PARAMETERS                                   INPUT COEFFICIENTS

   T=    580500.000      TF=       1.000000              CDCER=          0.0
   M=      1.000000     O&M=       0.0                   CDEXP=          0.0
  CF=      1.000000      Z1=       1.000000              CICER=          0.000724
 PHI=      1.000000      Z2=      60.000000              CIEXP=          1.000000
   R=      0.0           Z3=      60.000000              BYEAR=              1979
  DF=      1.000000      Z4=      60.000000      Z5=         0.0           Z6=          0.0

  CALCULATED VALUES     PANEL      SUM TO  1.4.2.1                          $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                              0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                            0.001

#RM =T / M                                                              580500.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                              1.000

CTFU=(CLRM / E)X((#RM X  Z1+.5)XX(E) -0.5XX(E))                              420.416


CTB =((CLRM/E)X((#RM X   Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3           420.412

CIPS=CTB*Z4/Z2                                                               420.412

   CRCI  =CTB  X R                                                             0.0
          PRE-IOC  CRCI =CRCI X Z6                                             0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                       0.0

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE    0.0       0.000619    0.0
   EACH PANEL USES 18 HAT SECTIONS TOTALING 584.25 KG (1288 LBS)
   WITH COST ESTIMATE OF $1.058/KG ($.48/LB).
```

```
                     ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.4.2.1.2   WIDE FLANGES

                     INPUT PARAMETERS                               INPUT COEFFICIENTS

     T=      580500.000      TF=        1.000000         CDCER=         0.0
     M=          1.000000    O&M=       0.0              CDEXP=         0.0
    CF=          1.000000    Z1=        1.000000         CICER=         0.000595
   PHI=          1.000000    Z2=       60.000000         CIEXP=         1.000000
     R=          0.0         Z3=       60.000000         BYEAR=            1979
    DF=          1.000000    Z4=       60.000000    Z5=         0.0          Z6=        0.0

     CALCULATED VALUES        PANEL        SUM TO   1.4.2.1                   $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                              0.0

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                            0.001

  #RM =T / M                                                              580500.000

  E   =1.0 + LOG(PHI) / LOG(2.0)                                              1.000

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                               345.352

  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3          345.349

  CIPS=CTB*Z4/Z2                                                               345.349

     CRCI   =CTB   X R                                                           0.0
            PRE-IOC  CRCI =CRCI X Z6                                             0.0
            POST-IOC CRCI =CRCI X (1.0-Z6)                                       0.0

     CO&M   =O&M OR CTB*Z5/Z2/ENYR                                               0.0

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0        0.000508     0.0
```

RUCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.4.2.1.3 TUBE BRACES & HARDWARE

```
             INPUT PARAMETERS                                     INPUT COEFFICIENTS

  T=     580500.000      TF=        1.000000            CDCER=          0.0
  M=       1.000000      O&M=       0.0                 CDEXP=          0.0
  CF=      1.000000      Z1=        1.000000            CICER=          0.000869
  PHI=     1.000000      Z2=       60.000000            CIEXP=          1.000000
  R=       0.0           Z3=       60.000000            BYEAR=             1979
  DF=      1.000000      Z4=       60.000000     Z5=          0.0         Z6=          0.0

  CALCULATED VALUES      PANEL         SUM TO  1.4.2.1                       $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                              0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                            0.001

#RM =T / M                                                                580500.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                 1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                504.675

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3            504.671

CIPS=CTB*Z4/Z2                                                                504.671

    CRCI  =CTB  X R                                                            0.0
          PRE-IOC  CRCI =CRCI X Z6                                             0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                       0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                               0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0        0.000743    0.0
    INCLUDES 4 TUBE BRACES 4.76M LONG,
    FRONT & REAR CLEVIS FITTINGS,CAST MOUNTINGS,WELD ROD,
    AND PROVIDES FOR OVERALL SCRAP ALLOWANCES.
```

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
   TABLE    1.4.2.1.4   ASSEMBLY & INSTALLATION

                  INPUT PARAMETERS                                      INPUT COEFFICIENTS

      T=      580500.000       TF=        1.000000          CDCER=          0.0
      M=        1.000000     O&M=        0.0                CDEXP=          0.0
     CF=        1.000000       Z1=        1.000000          CICER=          0.001231
    PHI=        1.000000       Z2=       60.000000          CIEXP=          1.000000
      R=        0.0            Z3=       60.000000          BYEAR=              1979
     DF=        1.000000       Z4=       60.000000    Z5=          0.0         Z6=          0.0

     CALCULATED VALUES        PANEL       SUM TO  1.4.2.1                        $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 0.0

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               0.001

  #RM =T / M                                                                  580500.000

  E    =1.0 + LOG(PHI) / LOG(2.0)                                                1.000

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                  714.591


  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3            714.585

  CIPS=CTB*Z4/Z2                                                                  714.585

     CRCI  =CTB  X R                                                               0.0
           PRE-IOC  CRCI =CRCI X Z6                                                0.0
           POST-IOC CRCI =CRCI X (1.0-Z6)                                          0.0

     CO&M  =O&M OR CTR*Z5/Z2/ENYR                                                  0.0

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0        0.001052    0.0
```

```
            ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
   TABLE   1.4.2.2.1  FOOTING CONCRETE & RE-BAR

                 INPUT PARAMETERS                            INPUT COEFFICIENTS

    T=     580500.000      TF=        1.000000        CDCER=          0.0
    M=          1.000000   O&M=       0.0             CDEXP=          0.0
   CF=          1.000000   Z1=        1.000000        CICER=          0.000143
  PHI=          1.000000   Z2=       60.000000        CIEXP=          1.000000
    R=          0.0        Z3=       60.000000        BYEAR=              1979
   DF=          1.000000   Z4=       60.000000   Z5=        0.0         Z6=         0.0

   CALCULATED VALUES       PANEL      SUM TO  1.4.2.2                       $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                               0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                             0.000

#RM =T / M                                                              580500.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                              1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                 82.861

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3            82.860

CIPS=CTB*Z4/Z2                                                                 82.860

    CRCI  =CTB  X R                                                             0.0
          PRE-IOC  CRCI =CRCI X Z6                                              0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                        0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE    0.0       0.000122   0.0
    CONCRETE ESTIMATED AT 6.8 CU YDS OF 5 SACK CEMENT.
    MIX 3196 LBS CEMENT, 9520 LBS SAND,
    12444 LBS 1-1.5 INCH ROCK.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.4.2.2.2 MACHINGERY & EQUIPMENT - GRS CONSTRUCTION

```
                 INPUT PARAMETERS                                   INPUT COEFFICIENTS

   T=          1.000000    TF=        1.000000          CDCER=          0.0
   M=          1.000000    O&M=       1.569673          CDEXP=          0.0
  CF=          1.000000    Z1=        1.000000          CICER=         26.161194
 PHI=          1.000000    Z2=       60.000000          CIEXP=          1.000000
   R=          0.003333    Z3=        8.000000          BYEAR=             1979
  DF=          1.000000    Z4=        2.000000    Z5=          0.0           Z6=        1.000000

  CALCULATED VALUES        SET        SUM TO  1.4.2.2                              $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                    0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                 26.161

#RM =T / M                                                                        1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                    1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                      26.161

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3                  26.161

CIPS=CTB*Z4/Z2                                                                       0.872

    CRC1  =CTB  X R                                                                  0.087
           PRE-IOC  CRC1 =CRC1 X Z6                                                  0.087
           POST-IOC CRC1 =CRC1 X (1.0-Z6)                                            0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                     1.570

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0        22.360001     1.341600
    HEAVY DUTY EQUIPMENT.  2 SETS FOR SEQUENCED CONSTRUCTION.  RC1 SETS
    THREE TIMES OVER 30 YEAR PERIOD.  71/2 YEAR LIFE WITH MAINTENANCE.
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.4.2.2.3 CONSTRUCTION OPERATIONS

```
                  INPUT PARAMETERS                                INPUT COEFFICIENTS

     T=     399600.000      TF=        1.000000          CDCER=           0.0
     M=     399600.000     O&M=        0.0               CDEXP=           0.0
    CF=       1.000000      Z1=        1.000000          CICER=           0.000176
   PHI=       1.000000      Z2=       60.000000          CIEXP=           1.000000
     R=       0.0           Z3=       60.000000          BYEAR=              1979
    DF=       1.000000      Z4=       60.000000    Z5=         0.0        Z6=         1.000000

    CALCULATED VALUES     MANDAYS        SUM TO  1.4.2.2                    $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                           0.0

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                        70.130

 #RM =T / M                                                              1.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                          1.000

 CIFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                             70.130


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3          70.130

 CIPS=CTB*Z4/Z2                                                             70.130

    CRCI  =CTB  X R                                                          0.0
          PRE-IOC  CRCI =CRCI X Z6                                           0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                     0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                             0.0

 COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0        0.000150    0.0
     270 WORK DAYS FOR CREW OF 1480
```

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE 1.4.2.3 SUPPORT STRUCTURE DDT&E

```
                INPUT PARAMETERS                                        INPUT COEFFICIENTS

   T=        1.000000     TF=     1.000000          CDCER=        2.340000
   M=        1.000000    O&M=     0.0               CDEXP=        0.300000
  CF=        1.000000     Z1=     1.000000          CICER=        0.0
 PHI=        1.000000     Z2=    60.000000          CIEXP=        0.0
   R=        0.0          Z3=    60.000000          BYEAR=           1979
  DF=        1.000000     Z4=    60.000000    Z5=        0.0         Z6=        0.0

  CALCULATED VALUES      SET        SUM TO  1.4.2                          $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                            2.340

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                          0.0

#RM =T / M                                                                1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                            1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                               0.0

CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3            0.0

CIPS=CTB*Z4/Z2                                                               0.0

    CRCI  =CTB  X R                                                          0.0
          PRE-IOC  CRCI =CRCI X Z6                                           0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                     0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                             0.0

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE    2.000000   0.0      0.0
```

1.4.3 POWER COLLECTION

This element of the GRS includes rectenna array elements associated with the actual reception and rectification of microwave energy. These array elements are in series and parallel as required to deliver the line output voltage and current. Also included are those components that accept dc power from array elements and route, control, convert, and switch this power for delivery to power conversion stations of the grid interface.

Incident microwave energy from the satellite is estimated to total 6.15 GW within an elliptical area with major and minor axes of 13 km and 10 km, respectively. The rectenna area is arbitrarily divided into five concentric zones, with power received per unit area diminishing from the center to the edge. Figure 1.4-9 shows these zones plotted for the 10×13-km (reference) rectenna, along with some of the other assumed rectenna characteristics.

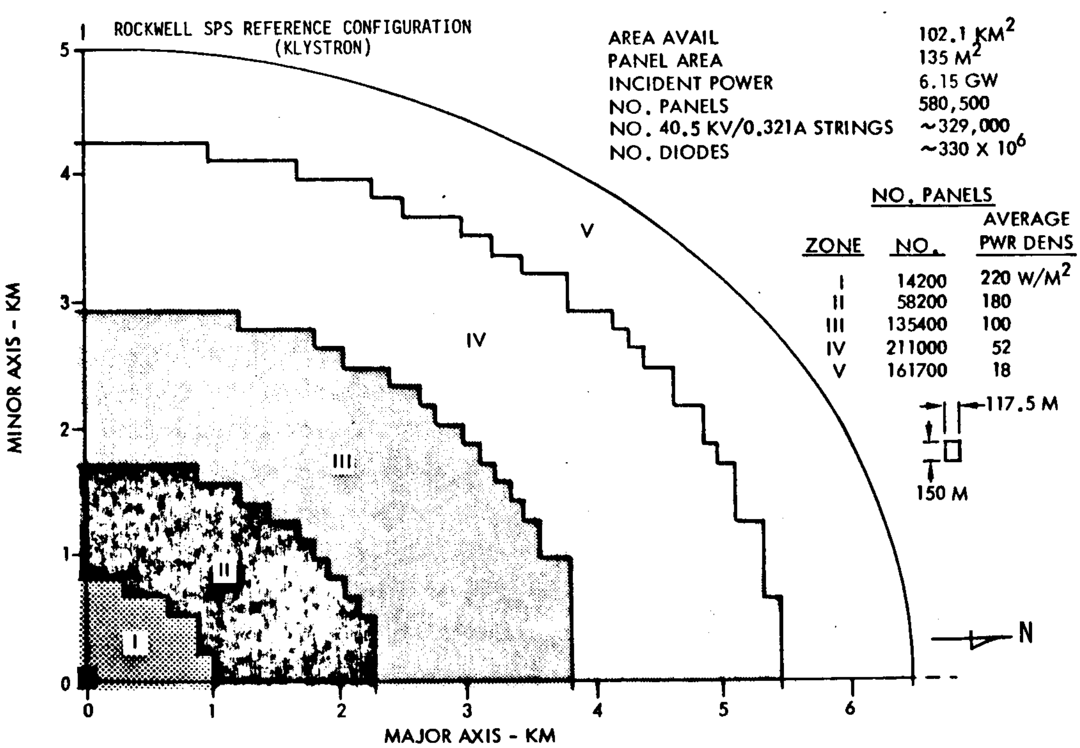


Figure 1.4-9. Rectenna Power Density Pattern (34°N Latitude)

Rectifier assemblies (rectenna panel electronics) consist of GaAs diodes and input/output filters. The outputs of these circuits are series connected to produce outputs of 40 kV as shown in Figure 1.4-10. Power regulation equipment accepts voltage from the series connected rectenna diodes and adjusts voltage outputs to power distribution feeders at values consistent with a positive current flow. Rectenna array elements are 0.735×9.33 m in size, and 20 elements are combined per panel with diode circuitry equivalent to the microwave density pattern. A total of 735 diodes or diode equivalents are required per average panel with a rectenna total of 330×10^6 diodes as shown in Figure 1.4-11.

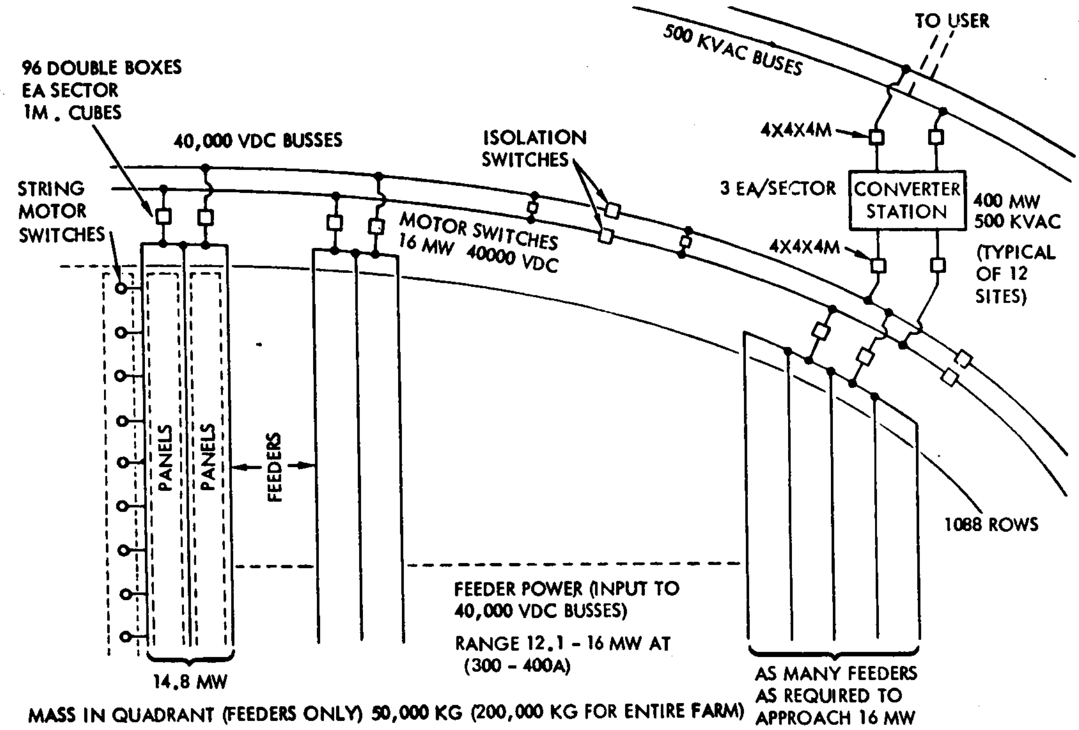


Figure 1.4-10. Rectenna Schematic Block Diagram (Preliminary)

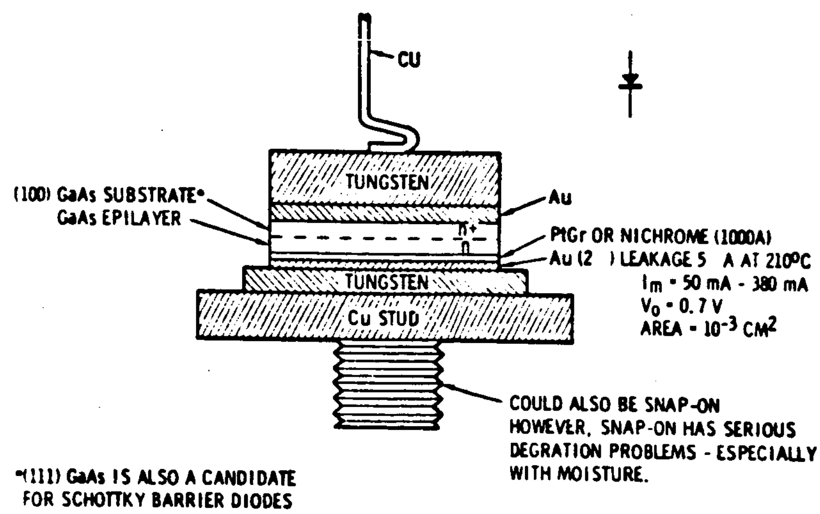
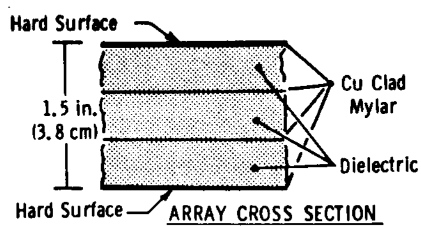


Figure 1.4-11. Diode Concept

Electronic array elements of the antenna are multilayered copper/dielectric sandwich panel material. Resource/mass projections are identified in Figure 1.4-12 based on the array cross section and panel requirements shown in the illustration. Costs were then determined from estimating guides/industrial contacts to provide a cost estimate of $\$1088 \times 10^6$ for all antenna array elements (Table 1.4-8). The addition of costs for switches and regulators needed at each panel provides a cost estimate of \$2272/panel.

580,500 RECTENNA PANELS

• DIELECTRIC		
PLASTIC COMPOUND—3.5 LB/FT^3, 0.4375 LB/FT^2 x 856.4 x 10^6 FT^2	-	374.68 x 10^6 LB
• MYLAR		
0.001-IN. THICKNESS AT 87.36 LB/FT^3, 0.02913 LB/FT^2 x 856.4 x 10^6 FT^2	-	24.95 x 10^6 LB
• COPPER		
0.0039 THICKNESS AT 556.6 LB/FT^3, 0.118752 LB/FT^2 x 856.4 x 10^6 FT^2	-	101.70 x 10^6 LB
• DIODES		
1 OZ. PER 426.67 x 10^6 DIODES OR EQUIV.	-	26.67 x 10^6 LB
TOTAL		528 x 10^6 LB
		909.6 LB/PANEL
		412.6 KG/PANEL



- 20 ARRAY ELEMENTS/PANEL
- 1475 FT^2 (137 M^2) PER PANEL
- 1990 TECHNOLOGY
- 1977 PRICES

Figure 1.4-12. Resource Requirements Rectenna Dipole —Bow-Tie—Panel Array Elements

The power collection and distribution system consists of all field feeders (collectors), supporting switch gear, 40-kV dc buses to the power converters, and the towers/footings needed to support the transmission lines. Approximately 330,000 switch gears, 10^7 meters of feeder cables, miscellaneous junction boxes, etc., must be delivered and installed at the panel sites. Tractor/trailer trucks are used for this purpose and proceed through the panel rows, delivering material at each panel. Additional trucks with reels play out the feeders, which then are installed in conduits and spliced to panel connections by the electrical installation crew. Contacts with a utility company indicate a requirement of eight man-hours to hook up one panel. On this basis, the manpower and equipment projections were established for a 20-hour 7-day week.

Equipment for electrical hookup and checkout of completed panels was calculated on the basis of acquisition cost prorated over the service life and

utilization period at a particular site. Total crew requirements of 4196 personnel and the schedule period were the basis of calculating man-day requirements of 755,280. The amortized cost of equipment and labor was combined for the total cost factor.

Table 1.4-8. Rectenna Dipole—Bow-Tie—Panel Array Elements

• Total panel area: 9.33 m × 14.69 m × 580,500 panels = 79.56×10^6 m^2 (30.61 ft×48.19 ft×580,500 panels = 856.4×10^6 ft^2)	
• Dielectric: 0.4375 lb/ft^2 × 856.4×10^6 ft^2 @ \$1.02/lb	= $\$382.27\times10^6$
• Mylar/surface: 4 layers × 856.4×10^6 ft^2 @ \$0.117 ft^2	= $\$400.80\times10^6$
• Copper (processed/bonded): 65% coverage 856.4 × 10^6 ft^2 @ \$0.175/ft^2	= $\$\ 97.69\times10^6$
• Diodes/equivalents/wire: 426.67×10^6 diodes @ \$0.117 each	= $\$\ 49.92\times10^6$
• Bonding: 6 surfaces 856.4×10^6 ft^2 @ \$0.0307/ft^2	= $\$157.51\times10^6$
(1979 Dollars) Total panel area cost	$\$1088.19\times10^6$ (\$1874.57/panel)

DDT&E power collection costs are associated with the design and verification of bow-tie electronic panels/bonding processes, connectors, and large switch gear to optimize the voltage/current ratios and element/wiring configuration. Cost estimates are provided in the following areas:

Area	Table
Antenna Array Elements	1.4.3.1
Power Distribution System	1.4.3.2
Installation and Checkout	1.4.3.3
Power Collection DDT&E	1.4.3.4

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.4.3.1 ANTENNA ARRAY ELEMENTS

INPUT PARAMETERS						INPUT COEFFICIENTS			
T=	580500.000	TF=	1.000000			CDCER=	0.0		
M=	1.000000	O&M=	0.0			CDEXP=	0.0		
CF=	1.000000	Z1=	1.000000			CICER=	0.002272		
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000		
R=	0.0	Z3=	60.000000			BYEAR=	1979		
DF=	1.000000	Z4=	60.000000	Z5=	0.0			Z6=	0.0

CALCULATED VALUES PANEL SUM TO 1.4.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.002
#RM =T / M	580500.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	1318.978
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	1318.967
CIPS=CTB*Z4/Z2	1318.966
CRC1 =CTB X R	0.0
PRE-IOC CRC1 =CRC1 X Z6	0.0
POST-IOC CRC1 =CRC1 X (1.0-Z6)	0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 0.0 0.001942 0.0

```
                 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
     TABLE    1.4.3.2     POWER DISTRIBUTION SYSTEM

                 INPUT PARAMETERS                              INPUT  COEFFICIENTS

     T=      580500.000       TF=         1.000000       CDCER=          0.0
     M=         1.000000     O&M=         0.0            CDEXP=          0.0
    CF=         1.000000      Z1=         1.000000       CICER=          0.000140
   PHI=         1.000000      Z2=        60.000000       CIEXP=          1.000000
     R=         0.0           Z3=        60.000000       BYEAR=             1979
    DF=         1.000000      Z4=        60.000000   Z5=          0.0        Z6=          0.0

     CALCULATED VALUES        PANEL         SUM TO  1.4.3                        $,MILLIONS

  CD=CDCER X (T X DF)XX(CDEXP) X CF                                                0.0

  CLRM=CICER X (M)XX(CIEXP) X CF X TF                                              0.000

  #RM =T / M                                                                580500.000

  E   =1.0 + LOG(PHI) / LOG(2.0)                                                  1.000

  CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                  81.502


  CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3             81.501

  CIPS=CTB*Z4/Z2                                                                  81.501

     CRCI   =CTB  X R                                                              0.0
            PRE-IOC  CRCI =CRCI X Z6                                               0.0
            POST-IOC CRCI =CRCI X (1.0-Z6)                                         0.0

     CO&M   =O&M OR CTB*Z5/Z2/ENYR                                                 0.0

  COMMENTS
     1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0         0.000120    0.0
```

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
      TABLE   1.4.3.3     INSTALLATION & CHECKOUT

                      INPUT PARAMETERS                                     INPUT COEFFICIENTS

       T=      781100.000        TF=          1.000000              CDCER=          0.0
       M=        4340.00000      O&M=         0.0                   CDEXP=          0.0
      CF=           1.000000     Z1=          1.000000              CICER=          0.000234
     PHI=           1.000000     Z2=         60.000000              CIEXP=          1.000000
       R=           0.0          Z3=         60.000000              BYEAR=             1979
      DF=           1.000000     Z4=         60.000000     Z5=            0.0         Z6=           0.0

      CALCULATED VALUES     MANDAYS         SUM TO  1.4.3                                $,MILLIONS

   CD=CDCER X (T X DF)XX(CDEXP) X CF                                                    0.0

   CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                  1.016

   #RM =T / M                                                                   179.977

   E   =1.0 + LOG(PHI) / LOG(2.0)                                                1.000

   CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                       182.777

   CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))         ) / Z3                   182.777

   CIPS=CTB*Z4/Z2                                                                       182.777

      CRCI  =CTB  X R                                                                   0.0
             PRE-IOC  CRCI =CRCI X Z6                                                   0.0
             POST-IOC CRCI =CRCI X (1.0-Z6)                                             0.0

      CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                      0.0

    COMMENTS
      1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0          0.000200     0.0
```

```
              ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE    1.4.3.4     POWER COLLECTION-DDT&E

               INPUT PARAMETERS                             INPUT COEFFICIENTS

  T=          1.000000    TF=        1.000000        CDCER=          3.510000
  M=          1.000000   O&M=        0.0             CDEXP=          0.300000
 CF=          1.000000    Z1=        1.000000        CICER=          0.0
PHI=          1.000000    Z2=       60.000000        CIEXP=          0.0
  R=          0.0         Z3=       60.000000        BYEAR=             1979
 DF=          1.000000    Z4=       60.000000    Z5=          0.0        Z6=        0.0

  CALCULATED VALUES       SET        SUM TO  1.4.3                         $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                              3.510

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                            0.0

#RM =T / M                                                                 1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                             1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                 0.0


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3            0.0

CIPS=CTB*Z4/Z2                                                                 0.0

  CRCI   =CTB   X R                                                            0.0
      PRE-IOC  CRCI  =CRCI X Z6                                                0.0
      POST-IOC CRCI  =CRCI X (1.0-Z6)                                          0.0

  CO&M   =O&M OR CTB*Z5/Z2/ENYR                                                0.0

COMMENTS
  1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     3.000000    0.0        0.0
```

1.4.4 CONTROL

The telemetry, tracking, communications, monitoring of microwave beam characteristics, computing phase corrections, and the equipment needed to provide frequency standard signals for the satellite are included in this section. This hardware will be used to monitor and control the satellite from the ground.

The following monitor and control functions are performed:

1. Tracking, using ground-based radars to monitor the orbital stability of the satellite.

2. Beam monitoring and control, using ground equipment for adaptive or command control of the satellite microwave beam.

3. Data management, using equipment required to analyze signals and data from the satellite and ground-based systems to compute control signals and corrective data to maintain safe and optimum performance.

4. Communications, using equipment required to maintain communications between the ground station and the SPS satellite. Included are the communications with the crew, and telemetry and command equipment not included in the beam monitoring and control assembly.

At this time, the cost effort is divided into the three categories of control center equipment, beam control electronics, and DDT&E. Two sets of full-up IBM 370, or equivalents, a complete display center, and a manned control room are envisioned as basic elements of the control center. Beam control electronics would consist of control sensors and dual frequency transmitters. The overall DDT&E and hardware costs were projected by engineering. The exacting requirement of this rectenna operation will require further study in future contract activity to define the technical and performance standards. It should also be noted that system and operational requirements are needed to define adequate software/ programming considerations.

Cost estimates are presented as follows:

Table 1.4.4.1 Control Center Equipment

Table 1.4.4.2 Control Electronics

Table 1.4.4.3 Control DDT&E

```
                    ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
      TABLE    1.4.4.1     CONTROL CENTER EQUIPMENT

                     INPUT PARAMETERS                                      INPUT COEFFICIENTS

       T=          1.000000     TF=          1.000000           CDCER=          0.0
       M=          1.000000    O&M=          0.0                CDEXP=          0.0
      CF=          1.000000     Z1=          1.000000           CICER=         17.549988
     PHI=          1.000000     Z2=         60.000000           CIEXP=          1.000000
       R=          0.0          Z3=         60.000000           BYEAR=              1979
      DF=          1.000000     Z4=         60.000000      Z5=          0.0         Z6=          0.0

      CALCULATED VALUES        SET          SUM TO  1.4.4                           $,MILLIONS

   CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 0.0

   CLRM=CICER X (M)XX(CIEXP) X CF X TF                                              17.550

   #RM =T / M                                                                    1.000

   E   =1.0 + LOG(PHI) / LOG(2.0)                                                1.000

   CTFU=(CLRM / E)X((#RM X  Z1+.5)XX(E) -0.5XX(E))                                  17.550


   CTB =((CLRM/E)X((#RM X     Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3             17.550

   CIPS=CTB*Z4/Z2                                                                   17.550

       CRCI   =CTB   X R                                                             0.0
                PRE-IOC  CRCI =CRCI X Z6                                             0.0
                POST-IOC CRCI =CRCI X (1.0-Z6)                                       0.0

       CO&M   =O&M OR CTB*Z5/Z2/ENYR                                                 0.0

   COMMENTS
       1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0        15.000000    0.0
```

RUCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.4.4.2 CONTROL ELECTRONICS

```
                        INPUT PARAMETERS                                   INPUT COEFFICIENTS

    T=          1.000000     TF=          1.000000           CDCER=          0.0
    M=          1.000000     O&M=         0.0                CDEXP=          0.0
   CF=          1.000000     Z1=          1.000000           CICER=         70.199997
  PHI=          1.000000     Z2=         60.000000           CIEXP=          1.000000
    R=          0.0          Z3=         60.000000           BYEAR=             1979
   DF=          1.000000     Z4=         60.000000   Z5=          0.0          Z6=          0.0

   CALCULATED VALUES         SET          SUM TO  1.4.4                            $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                              70.200

#RM =T / M                                                                     1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                  1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                  70.200

CTB =((CLRM/E)X((#RM X   Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3                70.200

CIPS=CTB*Z4/Z2                                                                  70.200

    CRCI  =CTB  X R                                                               0.0
          PRE-IOC  CRCI =CRCI X Z6                                                0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                          0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                  0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0      60.000000    0.0
```

```
              ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
   TABLE   1.4.4.3    CONTROL DDT&E

              INPUT PARAMETERS                                  INPUT COEFFICIENTS

     T=          1.000000    TF=        1.000000        CDCER=        11.700001
     M=          1.000000   O&M=        0.0             CDEXP=         1.000000
    CF=          1.000000    Z1=        1.000000        CICER=         0.0
   PHI=          1.000000    Z2=       60.000000        CIEXP=         0.0
     R=          0.0         Z3=       60.000000        BYEAR=            1979
    DF=          1.000000    Z4=       60.000000   Z5=          0.0       Z6=          0.0

    CALCULATED VALUES        SET       SUM TO  1.4.4                     $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                          11.700

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                         0.0

 #RM =T / M                                                               1.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                           1.000

 CIFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                              0.0


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3           0.0

 CIPS=CTB*Z4/Z2                                                              0.0

    CRCI  =CTB  X R                                                          0.0
          PRE-IOC  CRCI =CRCI X Z6                                           0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                     0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                             0.0

 COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE   10.000000    0.0        0.0
```

1.4.5 GRID INTERFACE

This element includes power conversion equipment that receives electrical power from the power collection system and conditions/converts it to a high voltage dc or ac power acceptable for input into the national power grid.

Converter stations accept 40 kV dc power and output 500 kV ac or dc. The concept utilizes a solid-state inversion/step-up concept typified by an existing dc - ac conversion station located in Sylmar, California. Although specific design details of this system await clarification in a future study effort, an analysis and cost estimate was prepared as shown in Table 1.4-9.

Table 1.4-9. Grid Interface (WBS 1.4.5)

ITEM DESCRIPTION	SPECIFICATION	GRS QUANTITY	PROJECTED UNIT COST	TOTAL (1979 $)
CONVERTER STATIONS	400 mW 500 kV ac or kV dc	12 EA.	$\$11.7 \times 10^6$	$\$140.389 \times 10^6$
ISOLATION SWITCH-GEAR	4×4×4 m	36 EA	$468,000 EA	$\$16.848 \times 10^6$
FILTER YARDS		12	$117,000 EA	$\$1.404 \times 10^6$
INTERCONNECT TOWERS & FOUNDATION	500 kV ac TOWERS	90 EA	$165,600 EA	$\$14.904 \times 10^6$
INTERCONNECT TRANSMISSION CABLE	12 LINES	120 MILES	$105,300/MI	$\$12.636 \times 10^6$
TOTAL/GRS				$\$186.181 \times 10^6$

The CER for grid interface DDT&E was derived from cost estimates in the "Technical Study Report on Pacific Northwest-Southwest dc Inter-tie," prepared by the Bonneville Power Administration in February, 1976. This DDT&E estimate was based on six cost quotations which Bonneville received on a 1.44 GW and a 2.20 GW inter-tie. The total cost for the 1.44 GW terminal ($156.7 M) was allocated as 30% DDT&E and 70% ICI. This judgment was based on the assumption that most of the facility will be a standard design.

Cost estimates are presented in Table 1.4.5.1 on electrical equipment and in Table 1.4.5.2 on DDT&E.

```
                ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE   1.4.5.1    ELECTRICAL EQUIPMENT

              INPUT PARAMETERS                                        INPUT COEFFICIENTS

   T=          1.000000     TF=        1.000000          CDCER=         0.0
   M=          1.000000     O&M=       0.0               CDEXP=         0.0
  CF=          1.000000     Z1=        1.000000          CICER=      186.180939
 PHI=          1.000000     Z2=       60.000000          CIEXP=        1.000000
   R=          0.0          Z3=       60.000000          BYEAR=           1979
  DF=          1.00000C     Z4=       60.000000     Z5=           0.0       Z6=        1.000000

  CALCULATED VALUES          SET         SUM TO  1.4.5                           $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                   0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               186.181

#RM =T / M                                                                         1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                     1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                    186.181


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               186.181

CIPS=CTB*Z4/Z2                                                                    186.181

   CRCI  =CTB  X R                                                                  0.0
         PRE-IOC  CRCI =CRCI X Z6                                                   0.0
         POST-IOC CRCI =CRCI X (1.0-Z6)                                             0.0

   CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                     0.0

COMMENTS
   1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0       159.128998    0.0
   COSTS BASED ON ITEMIZED REQUIREMENTS FOR ROCKWELL DESIGN.  12 CONVERTERS
   STATIONS, 36 ISOLATION SWITCH GEAR, 12 FILTER YARDS, 90 INTERCONNECT
   TOWERS/FOUNDATIONS, AND INTERCONNECT TRANSMISSION CABLE.
```

RUCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980

TABLE 1.4.5.2 GRID INTERFACE-DOTGE

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	5.000000	TF=	1.000000			CDCER=	44.126541
M=	1.000000	O&M=	0.0			CDEXP=	0.604000
CF=	1.000000	Z1=	1.000000			CICER=	0.0
PHI=	1.000000	Z2=	60.000000			CIEXP=	0.0
R=	0.0	Z3=	60.000000			BYEAR=	1979
DF=	1.000000	Z4=	60.000000	Z5=	0.0	Z6=	0.0

CALCULATED VALUES GW SUM TO 1.4.5	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	116.648
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.0
#RM =T / M	5.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	0.0
CIPS=CTB*Z4/Z2	0.0
CRCI =CTB X R	0.0
PRE-IOC CRCI =CRCI X Z6	0.0
POST-IOC CRCI =CRCI X (1.0-Z6)	0.0
CO&M =O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS
1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE 37.714996 0.0 0.0
CDCER/CDEXP BASED ON MSFC 1977 UTILITY INTERFACE INFORMATION.

1.4.6 OPERATIONS

This element includes the planning, development, and conduct of operations at the ground receiving station. It covers both direct and support personnel and expendable maintenance supplies required for ground station operation and maintenance.

Operations and maintenance personnel required after IOC are identified as a 300 personnel staff to provide a 24-hour operation, maintenance/repair, security, and administrative support (Table 1.4-10). A cost estimate for maintenance material (expendables, trucks, and equipment); standby auxiliary power; and test/support equipment is also identified in the table.

Table 1.4-10. Operations Requirements

ITEM	SHIFT	NO.	TOTAL	1979 DOLLARS
• OPERATIONS & MAINTENANCE PERSONNEL				
COMMAND & CONTROL CENTER (PERSONNEL + SUPERVISORY)	1	30		
	2	30		
	3	20	80	
CONVERTER STATION (TOTAL FOR 12 STATIONS)	1	36		
	2	36		
	3	36	108	
24-HOUR MAINTENANCE, REPAIR, SECURITY, & G&A/SUPPORT		112	112	
			300	
• MAINTENANCE MATERIAL				$\$15.362 \times 10^6$
EXPENDABLES, TRUCKS, EQUIP., UTILITIES, TEST/SUPPORT EQUIP.				

Cost estimates are shown in Table 1.4.6.1 for operations and maintenance personnel and in Table 1.4.6.2 for maintenance material.

```
                 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
TABLE    1.4.6.1     OPER. & MAINT. PERSONNEL

                 INPUT PARAMETERS                                     INPUT COEFFICIENTS

   T=       300.000000     TF=          1.000000         CDCER=          0.0
   M=       300.000000     O&M=        16.199997         CDEXP=          0.0
  CF=         1.000000     Z1=          1.000000         CICER=          0.0
 PHI=         1.000000     Z2=         60.000000         CIEXP=          0.0
   R=         0.0          Z3=         60.000000         BYEAR=              1979
  DF=         1.000000     Z4=         60.000000    Z5=          0.0          Z6=          0.0

   CALCULATED VALUES    PEOP/DAY        SUM TO  1.4.6                            $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 0.0

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               0.0

#RM =T / M                                                                     1.000

E   =1.0 + LOG(PHI) / LOG(2.0)                                                 1.000

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                    0.0


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3               0.0

CIPS=CTB*Z4/Z2                                                                    0.0

    CRCI  =CTB  X R                                                               0.0
          PRE-IOC  CRCI =CRCI X Z6                                                0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                          0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                16.200

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0        0.0        13.846150

    3 SHIFTS/DAY.  360 DAYS/YEAR. 300 PERSONS/DAY.  $150/PERSON
```

```
                 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
   TABLE    1.4.6.2     MAINT. MATERIAL

                 INPUT PARAMETERS                                  INPUT COEFFICIENTS

     T=         1.000000     TF=        1.000000          CDCER=         0.0
     M=         1.000000    O&M=       15.362101          CDEXP=         0.0
    CF=         1.000000     Z1=        1.000000          CICER=         0.0
   PHI=         1.000000     Z2=       60.000000          CIEXP=         0.0
     R=         0.0          Z3=       60.000000          BYEAR=              1979
    DF=         1.000000     Z4=       60.000000     Z5=          0.0     Z6=          0.0

     CALCULATED VALUES        SET        SUM TO  1.4.6                          $,MILLIONS

 CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 0.0

 CLRM=CICER X (M)XX(CIEXP) X CF X TF                                               0.0

 #RM =T / M                                                                     1.000

 E   =1.0 + LOG(PHI) / LOG(2.0)                                                 1.000

 CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                    0.0


 CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))        ) / Z3                 0.0

 CIPS=CTB*Z4/Z2                                                                    0.0

    CRCI  =CTB  X R                                                                0.0
          PRE-IOC  CRCI =CRCI X Z6                                                 0.0
          POST-IOC CRCI =CRCI X (1.0-Z6)                                           0.0

    CO&M  =O&M OR CTB*Z5/Z2/ENYR                                                 15.362

 COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0        0.0       13.130000
```

1.5 MANAGEMENT AND INTEGRATION

This element includes all efforts and material required for management and integration functions at the systems level and program level. It encompasses the following functions:

1. Program Administration
2. Program Planning and Control
3. Contracts Administration
4. Engineering Management
5. Manufacturing Management
6. Support Management
7. Quality Assurance Management
8. Configuration Management
9. Data Management
10. Systems Engineering and Integration

This element sums all direct effort required to provide management control including planning, organizing, directing, and coordinating the project to ensure that overall project objectives are accomplished. These efforts overlay functional work areas (e.g., engineering, manufacturing, etc.) and assure that they are properly integrated at higher levels. Also included are those efforts required in the coordination, gathering, and dissemination of management information, plus engineering efforts related to the establishment and maintenance of a technical baseline for a system by generation of system configuration parameters, criteria, and requirements. This includes requirements analysis and integration, system definition, system test definition, interfaces, safety, reliability, and maintainability. Efforts required to monitor system development and operations are part of this element to ensure that designs conform to the baseline specifications.

The management and integration function for DDT&E TFU, ICI, RCI and O&M are estimated at a cost equal to 5% of the corresponding total dollar estimates for WBS elements of the satellite (1.1), space construction and support (1.2), transportation (1.3), and the ground receiving station (1.4).

Cost estimates for management and integration charges are presented in Table 1.5 for the Rockwell reference SPS configuration.

```
TABLE    1.5        RUCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
                         MANAGEMENT AND INTEGRATION

                 INPUT PARAMETERS                                      INPUT COEFFICIENTS

    T=          0.0          TF=        1.000000            CDCER=          0.0
    M=          0.0         O&M=        0.0                 CDEXP=          0.0
   CF=          0.0          Z1=        1.000000            CICER=          0.0
  PHI=          1.000000     Z2=       60.000000            CIEXP=          0.0
    R=          0.0          Z3=       60.000000            BYEAR=              1979
   DF=          1.000000     Z4=       60.000000     Z5=           0.0         Z6=          0.0

   CALCULATED VALUES      5% * ALL        SUM TO  1                               $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                 1482.630

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                  0.0

#RM =T / M                                                                       0.0

E    =1.0 + LOG(PHI) / LOG(2.0)                                                  0.0

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                    2407.669


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                 0.0

CIPS=CTB*Z4/Z2                                                                     569.734

    CRCI   =CTB  X R                                                                 6.567
              PRE-IOC  CRCI =CRCI X Z6                                               3.395
              POST-IOC CRCI =CRCI X (1.0-Z6)                                         3.172

    CUO&M  =O&M OR CTB*Z5/Z2/ENYR                                                    3.535

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE     0.0        0.0        0.0
    DDT&E,TFU,IC1,RC1, AND O&M ARE
    CALCULATED AT 5% OF CORRESPONDING TOTALS
    FOR WBS 1.1 THROUGH 1.4
```

1.6 MASS CONTINGENCY

A cost contingency has been added to the SPS Program to provide for a 25% mass contingency due to the potential increased weight as a result of design/development activities that would affect the procurement of systems during any phase of the program. This allowance is costed as a 15% bottom line contingency to the DDT&E, TFU, ICI, RCI and O&M elements of the program. Table 1.6 presents the amounts in each of these areas based on the totals of space segment WBS line Items 1.1 - Satellite, and 1.2 - Space Construction and Support for the Rockwell Reference SPS Configuration. Space Transportation (WBS 1.3) was not included in these calculations as fleet sizes and number of flights were established on the basis of masses to orbit with a 25% contingency.

TABLE 1.6 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION,1980
MASS CONTINGENCY

```
                    INPUT PARAMETERS                                    INPUT COEFFICIENTS

    T=        0.0          TF=       1.000000          CDCER=       0.0
    M=        0.0          O&M=      0.0               CDEXP=       0.0
   CF=        0.0          Z1=       1.000000          CICER=       0.0
  PHI=        1.000000     Z2=      60.000000          CIEXP=       0.0
    R=        0.0          Z3=      60.000000          BYEAR=            1979
   DF=        1.000000     Z4=      60.000000     Z5=          0.0     Z6=          0.0

    CALCULATED VALUES                  SUM TO  1                                  $,MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF                                                  2454.463

CLRM=CICER X (M)XX(CIEXP) X CF X TF                                                  0.0

#RM =T / M                                                                      0.0

E   =1.0 + LOG(PHI) / LOG(2.0)                                                  0.0

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))                                     3085.372


CTB =((CLRM/E)X((#RM X    Z3 + 0.5)XX(E) -0.5XX(E))          ) / Z3                  0.0

CIPS=CTB*Z4/Z2                                                                      778.208

    CRCI  =CTB  X R                                                                   7.874
          PRE-IOC  CRCI =CRCI X Z6                                                    0.650
          POST-IOC CRCI =CRCI X (1.0-Z6)                                              7.224

    CO&M  =O&M OR CTP*Z5/Z2/ENYR                                                      3.009

COMMENTS
    1977 DATA ENTERED FOR CDCER,CICER, AND O&M WERE      0.0        0.0        0.0
    A 25% MASS CONTINGENCY IS COSTED AS A 15% COST CONTINGENCY ON 1.1, 1.2,
    TRANSPORTATION CALCULATIONS (WBS 1.3 ) FOR FLEET AND NUMBERS OF FLIGHTS
    ARE BASED ON MASSES WITH A 25% CONTINGENCY.
```